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ASSESSMENT OF THE ARCTIC GRAYLING SPORT FISHERY RESOURCES IN THE GULKANA RIVER DURING 1986, 1987, and 1988[1]

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ABSTRACT

Arctic grayling *Thymallus arcticus* were captured by electrofishing, hook and line, and weir trapping in the Gulkana River and two of its tributaries during 1986, 1987, and 1988. A total of 18,808 Arctic grayling were tagged and released in the Gulkana River drainage. Recaptures of tagged fish show that Arctic grayling in the Gulkana River undergo extensive intrastream and interstream migrations. No Arctic grayling tagged in the study have been reported recaptured outside of the Gulkana River drainage. Arctic grayling sampled in the Gulkana River during the study ranged from age 0 to age 7 and were predominantly age 3 and 4 fish. Data are presented on length distributions, capture probabilities, age composition, and mean length-at-age. Population estimates are discussed and future study directions are recommended.

KEY WORDS: Arctic grayling, *Thymallus arcticus*, Gulkana River, intrastream migration, interstream migration, mark-recapture, age, length.

INTRODUCTION

Located midway between Anchorage and Fairbanks along the Richardson Highway, the Gulkana River provides significant recreational value to the community of Glennallen as well as southcentral and interior Alaska. The Gulkana River supports the single largest recreational fishery in the Glennallen area (Table 1). It is now the single largest fishery (in terms of harvest) for Arctic grayling *Thymallus arcticus* in the state. In 1987, the Gulkana River accounted for 12.0% of the statewide harvest of Arctic grayling (Mills 1988). This represents an increase in harvest of over 100% from 1984. The largest percentage of this harvest occurs in the reach of the Gulkana River upstream from Sourdough; an area recently classified by the United States Congress as Wild and Scenic.

In addition to Arctic grayling, the Gulkana River supports the primary sport fishery in the Glennallen area for rainbow and steelhead trout *Oncorhynchus mykiss*, chinook salmon *O. tshawytscha*, and sockeye salmon *O. nerka*. The chinook and sockeye salmon stocks from the Gulkana River also support commercial, subsistence, and personal use fisheries.

Access to the Gulkana River for bank, float, and power-boat anglers is available at several locations along the Richardson Highway (Figure 1). Public land under Federal or State ownership accounts for approximately 70% of the land adjacent to the river. The West Fork, the Middle Fork, and the mainstem of the Gulkana River above Sourdough have been designated as Wild and Scenic by Congress and are administered by the Bureau of Land Management. This area is becoming increasingly popular with float anglers.

Effort and harvest by recreational anglers fishing the Gulkana River have been estimated annually with a postal mail survey since 1977 (Mills 1979-1988). In addition, on-site creel surveys have been conducted on the Gulkana River from 1975 through 1980 and during 1983 and 1986. Angler effort has increased an estimated 417% from 1977 to 1987 and the total estimated harvest of Arctic grayling has increased 301% during the same period (Mills 1979; Mills 1988).

Annual sampling of Arctic grayling in the Gulkana River from 1978 through 1982 indicates that the sport harvest is made up primarily of age 3 and 4 fish (Williams and Potterville 1983). The mean fork length of the sport harvest has remained relatively stable at approximately 280 mm from 1968 through 1982. There was, however, an observed decrease of approximately 40 mm in the maximum size of Arctic grayling in the sport harvest during that time (Williams and Potterville 1983).

Significant declines in Arctic grayling populations have occurred in recent years in several of the major interior Alaska fisheries. This has placed increased demand on the Gulkana River to meet the recreational needs of anglers targeting these fish. This has been reflected in increased numbers of float anglers in the upper reaches of the Gulkana River as well as increased numbers of boat and shore anglers in the remaining portions of the river. Angler effort by people floating the Gulkana River increased 68% from 1980 to 1983, and the catch of Arctic grayling by float anglers increased 272% during the same period (Williams and Potterville 1984). Previous creel survey data

Table 1. Gulkana River and Glennallen area recreational angler effort and Arctic grayling harvest, 1977 through 1987 (from Mills 1979-1988).

	Gulkana River		Glennallen Area			
Year	Effort[a]	Arctic Grayling	Effort[a]	% from Gulkana	Arctic Grayling	% from Gulkana
1977	12,446	5,929	51,485	24.2	25,991	22.8
1978	15,487	9,604	44,566	34.8	26,473	36.3
1979	25,073	13,789	57,266	43.8	37,232	37.0
1980	21,477	10,530	50,518	42.5	32,106	32.8
1981	22,332	11,933	53,499	41.7	32,982	36.2
1982	23,834	14,273	54,953	43.4	33,586	42.5
1983	24,347	12,369	51,276	47.5	26,832	46.1
1984	18,972	8,722	51,964	36.5	19,272	45.3
1985	20,773	15,622	48,707	42.7	32,615	47.9
1986	18,751	12,896	51,563	36.4	24,194	53.3
1987	24,848	13,324	51,120	48.6	27,359	48.7

[a] Effort in angler-days fished.

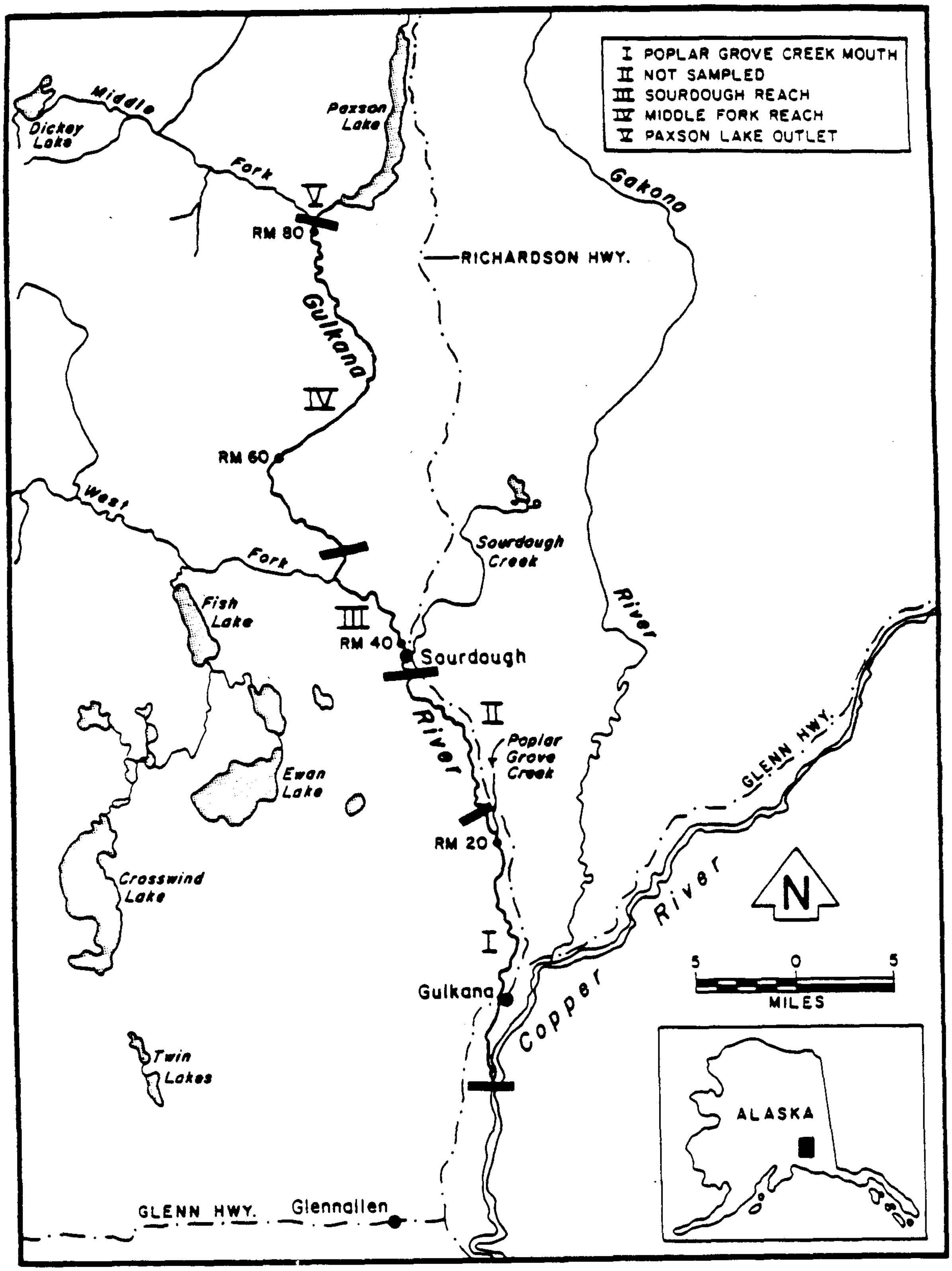

Figure 1. Map of the Gulkana River drainage.

indicate that the estimated harvest of Arctic grayling from the Gulkana River represents only about 12.5% of the total catch (Williams and Potterville 1985). Similarly, Roth and Delaney (1987) found that anglers harvested only 6.7% of the total sport catch of Arctic grayling for the period from 16 June through 17 August 1986.

Arctic grayling life history strategies vary from stocks which utilize a single river to stocks having complex migration patterns. In general, Arctic grayling begin an upstream spawning migration to mainstem river or tributary spawning areas in the spring. The migration is initiated as water temperatures reach 0.5 to 1.0 ^{o}C (Behlke et al. 1988, Tack 1980) and coincides with rising water flows and temperatures (Tack 1974). Spawning begins as temperatures reach 3.9 ^{o}C, occurs at or near flood stage (Tack 1980), and lasts from 1 to 3 weeks (Tack 1972, McPhee and Watts 1976, Tack and Fisher 1977). The grayling fry hatch in 2 to 4 weeks (Bishop 1971) and undergo a period of rapid summer growth in their natal areas to a length of approximately 100 mm (Morrow 1980). As water temperatures and flows decrease in the fall, the juvenile grayling migrate to deep pools, lakes, or larger river systems to overwinter (Tack 1980).

Most adult grayling leave the spawning areas shortly after spawning and migrate to summer feeding areas (McPhee and Watts 1976, Williams and Morgan 1974, and Williams 1975). After reaching the summer feeding areas by early July, intrastream movements decrease, although there may be migrations into cooler tributary waters during periods of low flows and high water temperatures in the main river (Tack 1980). Arctic grayling are generally distributed in clearwater rivers with the largest adults found the furthermost upstream in the prime feeding areas while the sub-adults and juveniles are found in the lower stream sections (Tack 1980). In the fall, Arctic grayling migrate out of the summer feeding areas to lakes, deep pools, or larger river systems to overwinter (Behlke et al. 1988, Tack 1980). This migration, triggered by decreasing flows and water temperatures, generally begins in September but may extend into December (Roguski and Tack 1970). Tack (1980) pointed out that Arctic grayling may have specific sites in which they spawn annually, and may have a homing tendency to return to the same river sections annually.

To formulate a long-term management plan for the Gulkana River, efforts were begun in 1986 to evaluate the magnitude and condition of the Arctic grayling stocks (Roth and Delaney 1987). The goal of the plan will be to maintain sustainable yield and historic age and size composition and prevent significant population declines while maintaining catch levels which are satisfactory to anglers. As an initial step in this plan, bag and possession limits for Arctic grayling in the Gulkana River were reduced for the 1989 season from ten to five fish, only one of which can be 14 inches or greater in length.

The goal of the Gulkana River project, through the construction of a data base of selected fishery statistics and population parameters, is the development of a sound fishery management regime of the Gulkana River recreational fisheries. Population abundance and biological information for Arctic grayling in the Gulkana River will provide the data base necessary to formulate the long-term management strategies needed to maintain the high quality of this fishery. This report presents the data collection efforts since 1986 which have been directed toward the development of methodologies suitable to determining population parameters, growth, and intrastream migrations for Arctic grayling in the Gulkana River. During the first portion of the study, the Arctic grayling spawning populations were surveyed in two major spawning tributaries of the Gulkana River; Sourdough and Poplar Grove Creeks. The second portion of the study was conducted in study reaches of the mainstem Gulkana River to survey Arctic grayling populations and their intrastream movements.

Specific objectives of this study were as follows:

1. Census the number of Arctic grayling migrating into Poplar Grove and Sourdough Creeks during May;

2. Estimate the age and length compositions of Arctic grayling migrating into Poplar Grove and Sourdough Creeks during May;

3. Estimate the abundance of Arctic grayling in selected reaches of the Gulkana River;

4. Estimate the age and length compositions of Arctic grayling in the mainstem Gulkana River; and

5. Determine the migrational movements of Arctic grayling in the Gulkana River during the open water period.

METHODS

Study Area

The Gulkana River is a tributary to the Copper River. The drainage (Figure 1) includes two major tributaries to the Gulkana River, West and Middle Forks, and several smaller tributaries including Sourdough and Poplar Grove Creeks. During the period of this study, weirs were placed on these two creeks and sampling was carried out in the mainstem of the river. The mainstem was divided into four major study reaches in this report, these being:

1. Poplar Grove Creek Mouth - from the mouth of Poplar Grove Creek downstream to the mouth of the Gulkana River,

2. Sourdough Reach - from 1.6 km upstream of the confluence with the West Fork downstream to the mouth of Sourdough Creek,

3. Middle Fork Reach - from the confluence with the Middle Fork downstream to 1.6 km above the West Fork, and

4. the outlet of Paxson Lake.

Although initially presented by Roth and Delaney (1987), the data collected on Arctic grayling during 1986 are also included in this report.

Sampling Design and Data Collection

Arctic grayling investigations were conducted throughout the Gulkana River from Paxson Lake downstream to the mouth using a variety of collection techniques during 1986, 1987, and 1988 (Table 2). For this report, adult Arctic grayling are defined as fish that were 200 mm fork length (tip of snout to fork of tail) or longer while juvenile grayling are all fish less than 200 mm fork length. Summaries of sampling dates, capture techniques, and numbers of fish sampled are presented by survey site in Appendices A1, A2, and A3.

1986:

Arctic grayling tagging was conducted at a weir operated in Poplar Grove Creek (Mile 138 of the Richardson Highway) approximately 91 meters above the Richardson Highway bridge from 18 May through 20 May. All Arctic grayling collected (including juveniles) were marked with an individually numbered Floy anchor tag (style FD 68B) and released (Appendix A4). Sampling site and date, fork length (FL) to the nearest 1 mm, and tag number were recorded for all fish. Scales were collected from the first 420 fish captured at the weir. One scale from each sampled fish was collected from the preferred area[1] and mounted on a gummed card. Arctic grayling were also collected in Poplar Grove Creek by dip-netting three sites downstream from the Richardson Highway as part of a culvert fish passage study (Behlke et al. 1988). Length data were collected and the fish were tagged with Floy streamer tags (style FSTL-73). No scale samples were collected from these fish. The tags used in the culvert study were temporary and were not recoverable during later sampling events. A portion of the grayling tagged at the lower sites were later recaptured at the upper weir and were measured and retagged with anchor tags (Behlke et al. 1988).

Three float surveys using hook and line collection techniques were conducted from the outlet of Paxson Lake downstream to Sourdough (Figure 1). The sampling during these surveys was conducted as the survey progressed downstream such that no reach was resampled during any one survey. All Arctic grayling collected were marked with an individually numbered Floy anchor tag and released (Appendix A4). Sampling site and date, fork length to the nearest 1 mm, and tag number were recorded for all fish collected and scales were taken from a random sample of the Arctic grayling captured. The tag number was recorded for all recaptured grayling, but the fish were not measured.

Boat electrofishing was used to sample the reach from 1.6 km upstream of the confluence with the West Fork downstream to Sourdough during August (Figure 1). The electrofishing equipment was a Coffelt Model VVP-3C unit powered by a 2.5 kilowatt Onan generator using pulsed DC (direct current) and a variable voltage system. The unit was equipped with a 3.7 m boom with five suspended electrodes mounted in a 5.5 m riverboat. All collected fish were

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[1] The left side of the fish approximately two rows above the lateral line and on the diagonal row downward from the posterior insertion of the dorsal fin (Clutter and Whitesel 1956).

Table 2. Summary of the Gulkana River Arctic grayling tagging data, 1986 through 1988.

Sample Date	Sample Reach	Capture Technique	Number Caught	Number Tagged	Number Recaptures	Number Killed
1986						
5/14-5/16	Poplar Grove Creek	Seine	850	850	0	0
5/16-5/20	Poplar Grove Creek	Weir	2,249	2,245	0	4
6/27-7/1	Paxson to Sourdough	Hook&Line	558	543	3	12
7/16-7/21	Paxson to Sourdough	Hook&Line	423	418	5	0
7/28-8/11	Paxson to Sourdough	Hook&Line	97	94	6	0
8/18-8/20	Sourdough Reach	Electro	1,136	911	49	0
1987						
5/10-5/17	Sourdough Creek	Weir	2,932	1,581	3	0
6/12-6/13	Poplar Grove Mouth	Electro	204	152	3	5
6/20	Paxson Lake Outlet	Electro	34	33	1	0
6/22-6/25	Sourdough Reach	Electro	1,103	951	104	18
6/27-6/29	Middle Fork Reach	Electro	370	355	17	5
7/14-7/15	Paxson Lake Outlet	Electro	60	53	4	1
7/16-7/19	Middle Fork Reach	Hook&Line	394	352	11	1
7/16-7/24	Middle Fork Reach	Electro	1,471	1,376	110	7
7/25-8/10	Sourdough Reach	Electro	387	292	106	2
8/21-8/24	Middle Fork Reach	Electro	220	186	24	3
8/25-8/26	Middle Fork Reach	Hook&Line	229	215	13	0
8/28-9/3	Sourdough Reach	Electro	1,142	989	91	4
9/15-9/19	Sourdough Reach	Electro	1,516	1,374	271	5
1988						
5/5-5/9	Sourdough Creek	Hook&Line	81	78	3	0
5/10-5/22	Poplar Grove Creek	Weir	5,255	4,711	198	0
6/23	Sourdough Reach	Electro	11	9	2	0
6/23-6/28	Middle Fork Reach	Hook&Line	172	156	16	0
7/23-7/27	Middle Fork Reach	Both[a]	84	77	5	0
8/5-8/27	Sourdough Reach	Electro	184	136	12	1
8/26-8/28	Middle Fork Reach	Both[a]	34	32	2	0
9/13-9/17	Sourdough Reach	Electro	787	606	57	0
9/20	Middle Fork Reach	Electro	13	11	2	0
9/24-9/25	Gulkana Mouth	Both[a]	22	22	0	0

[a] Electrofishing and Hook & Line.

measured and all Arctic grayling 200 mm FL or longer were measured, tagged, and released. A portion of the juvenile grayling were also tagged (Appendix A4). Scales were collected from a sample of the adult and juvenile grayling captured during the electrofishing survey. All recaptured fish were measured and the tag numbers were recorded.

1987:

Arctic grayling tagging was conducted at a weir operated in Sourdough Creek (Mile 146.5 of the Richardson Highway) approximately 0.4 km downstream of the Richardson Highway bridge from 9 May through 17 May. Immigrating Arctic grayling were collected by beach seining in the area just downstream of the weir. All Arctic grayling 200 mm FL or longer were marked with an individually numbered Floy anchor tag and released. Sampling site and date, fork length, and tag number were recorded for all fish tagged. Scales were collected from the first 500 Arctic grayling tagged at the weir. Three scales from each sampled fish were collected from the preferred area and mounted on a gummed card. All juvenile Arctic grayling collected at the weir were measured and scale samples were collected from the first 110 juvenile fish captured. All recaptured fish were measured and the tag numbers were recorded.

The four survey reaches in the mainstem Gulkana River (Figure 1) were each sampled at least once during 1987 (Table 2). Sampling in the Poplar Grove Creek mouth survey area was discontinued after the June survey due to low catches and hazardous sampling conditions. Sampling at the outlet of Paxson Lake was discontinued after July as low numbers of fish were captured at this site. In the Middle Fork reach, float surveys using hook and line were conducted during July and August to supplement the electrofishing collection efforts. The Sourdough and Middle Fork reaches were surveyed in June, July, and August, while only the Sourdough reach was sampled during September.

Boat-mounted electrofishing using pulsed DC and a variable voltage system was used to collect fish for tagging in the Gulkana River in 1987. The voltage was adjusted, depending on water conductivity, to maintain approximately 2 amps of output to minimize fish injury while maintaining catch rates. In the two lower study reaches (downstream of the West Fork) and at the outlet of Paxson Lake, the electrofishing equipment was a Coffelt Model VVP-3C unit powered by a 2.5 kilowatt Onan generator or a 3.5 kilowatt Homelite generator. The unit was equipped with a 3.7 m boom with three suspended electrodes mounted in a 6.1 m riverboat. In the middle study reach (Middle Fork downstream to the canyon), a Coffelt Model BP-1C backpack electrofishing unit provided the power to a 3.0 m boom with three suspended electrodes on a 4.9 m riverboat. In both systems, the boats acted as the cathodes and the electrodes served as the anodes. Power to the electrodes was controlled by a foot switch.

All Arctic grayling were measured and all fish 200 mm FL or longer were marked with an individually numbered Floy anchor tag and released. Scale samples were collected from a sample of the Arctic grayling (comprised of both juveniles and tagged adults) captured during all of the surveys except the hook and line sampling in the Middle Fork reach in July (Appendices A1 and A2). Tag numbers were recorded for all recaptured grayling and all recaptured fish were measured except during portions of the June and July sampling (Appendix A3).

1988:

Arctic grayling tagging was conducted at a weir operated in Poplar Grove Creek approximately 2.4 km downstream from the Richardson Highway bridge from 10 May through 22 May. Arctic grayling were collected by beach seining in the area just downstream of the weir. All Arctic grayling 200 mm FL or longer were measured, marked with an individually numbered Floy anchor tag, and released. Sampling site and date, fork length, and tag number were recorded for all fish tagged. Scales were collected from a sample of the Arctic grayling tagged during the first 3 days of the weir operation (Appendix A1). Differentiation by sex was possible for a portion of the adult grayling greater than 250 mm FL collected at the weir. Sex was recorded for those grayling where sexual dimorphism or the presence of milt or eggs was observed. Dimorphism was evident in the swelling of the anal vent or differences in the length of the dorsal fin (the dorsal fin of adult males reaches the adipose fin when depressed; Morrow 1980).

Juvenile Arctic grayling collected at the weir were measured during the first 2 days of sampling and scale samples were collected from the first 70 juvenile fish captured (Appendix A2). All other juvenile grayling captured at the weir were counted. All recaptured fish were measured and the tag numbers were recorded. Hook and line sampling was conducted in Sourdough Creek during May as high water conditions prevented the installation of a weir at this site. All captured grayling were measured and scales were collected. All recaptures were measured and tag numbers were recorded.

During 1988, most of the mainstem Gulkana River sampling effort took place in the Sourdough and Middle Fork reaches, where the Middle Fork reach is defined for 1988 to include all data collected from the outlet of Paxson Lake downstream to 1.6 km upstream of the confluence with the West Fork. Sampling was conducted using boat mounted electrofishing as described for the 1987 data collection efforts and was conducted in the Sourdough reach in June, August, and September and in the Middle Fork reach during July, August, and September (Table 2). Hook and line sampling was conducted in the Middle Fork reach during June, July, and August. Hook and line and electrofishing were conducted at the mouth of the Gulkana River during September.

All Arctic grayling collected during the summer sampling were measured and all fish 200 mm FL or larger were tagged. All recaptured fish were measured and the tag numbers were recorded. Scale samples were collected from all grayling captured by electrofishing in the Middle Fork reach, all grayling captured by hook and line on August 28 in the Middle Fork reach, all grayling captured in the Sourdough reach in August, and from a random sample of the grayling captured in the Sourdough reach during September (Appendices A1 and A2).

<u>Data Analyses</u>

The numbers of Arctic grayling caught and tags recaptured, mean length, length distributions, age compositions, and mean length-at-age were summarized by sampling event. A sampling event is defined as sampling occurring within a series of one or more days in one study reach and with one gear type. For instance, sampling with electrofishing gear in the Sourdough reach during the first week of July is one sampling event. Unless otherwise described, weir sampling is treated as one event.

Tag Ratios by Release and Recovery:

Tags were released and recaptured during most sampling events and the distribution of the recoveries provided information on the migrational behavior of the adult grayling over the sampling season. The choice of appropriate population estimators for the Gulkana River depended on the results of an analysis of tag recapture rates. Loglinear methods for categorical data (Agresti 1984) were used to test whether the rate of tag recovery was associated with time or location of the recovery event for each release. Loglinear methods allow for the analysis of association in three-dimensional tables. This includes testing whether there is interaction between any of the three factors (tag status, month of recovery, and location of recovery) or whether there is total independence, i.e. no interaction. The SYSTAT (Wilkinson 1988) procedure for categorical data was used to generate maximum-likelihood estimates for fitting loglinear models to the recovery data for each release event, and to generate fitted values and residuals. Models with a p-value less than 0.05 were rejected and the most parsimonious model was chosen.

Odds ratios provide a measure of association, where an odds ratio of one indicates independence between rows and columns. Odds ratios (θ) are estimated by (Agresti 1984);

$$\theta = (m_{11}/m_{12}) \ / \ (m_{21}/m_{22}) \tag{1}$$

where,

m_{ij} = predicted or (observed) number of fish in the ith row and jth column in a two-dimensional contingency table.

In the case of a tagging experiment, θ represents the ratio of two tagged-to-untagged rates, and an odds ratio of one for two sampling events indicates equal tagging rates for tagged fish over the two events.

Abundance Estimators:

The estimation of the abundance of Arctic grayling in the Gulkana River is one objective of this project, and two possible estimators were considered. First, a Petersen model was fit to the recovery of tags released at the Sourdough Creek weir in 1987 and recovered from the mainstem river to estimate total abundance of the population in the mainstem Gulkana River.

The abundance, $\hat{N}$, is estimated by Seber (1982);

$$\hat{N} = \frac{(M+1)(C+1)}{(R+1)} - 1 \tag{2}$$

and the variance by,

$$Var(\hat{N}) = \frac{(M+1)(C+1)(C-R)(M-R)}{(R+1)^2(R+2)} \tag{3}$$

where,

M = number of tagged grayling released at the weir,

R = number of recaptures in one or more sampling events, and

C = number of grayling examined for recaptures in one or more sampling events.

The assumptions for this estimate are:

1. the population is closed, i.e. there is no immigration or emigration between sampling events;
2. tagging does not affect the catchability of the grayling;
3. all grayling have an equal chance of being caught in both samples, or total mixing of tagged fish has occurred prior to the recapture sample; and,
4. there is no tagging mortality and all tags are reported.

Secondly, Arctic grayling were tagged and released in all inriver sampling events and these releases could also be used for estimating population size within the sampling reaches. However, if analysis of recapture rates show that there is migration between sampling reaches, which precludes the use of the Petersen estimator, a stratified estimator which allows for movement between strata can be used (Darroch 1961). When there are equal numbers of release and recovery strata, the stratified estimator (W) is (Seber 1982):

$$W = D_u M^{-1} a \tag{4}$$

where:

W = a vector with the estimates of the number of untagged fish in each recovery stratum;

D_u = a diagonal matrix of the number of untagged fish observed in each recovery stratum *j*;

M = a matrix of m_{ij}, the number of tagged fish in each recovery stratum, j, which were released in tagging stratum i; and,

a = a vector of the number of tagged fish released in tagging stratum i.

The number of Arctic grayling in each stratum at the time of recovery is the sum of the estimated number of untagged fish present and the number of tagged fish released in that stratum. The variance-covariance matrix of $\underline{W}$ was estimated using equations 11.20-11.23 on page 441 of Seber (1982). The variance of the point estimate for the total number of Arctic grayling present is the sum of the variance and covariance estimates for the individual strata.

Assumptions necessary for these abundance estimates are (Seber 1982):

1. All Arctic grayling in the j^{th} recovery stratum, whether tagged or untagged, have the same probability of being caught;

2. Tagged fish behave independently of one another with regard to moving among strata and being caught;

3. A tagged fish is as likely to be caught as an untagged fish;

4. All tagged fish are recognized as such during recovery;

5. There is no marking induced mortality; and,

6. The population is closed, i.e. there is no immigration or emigration from the strata during the duration of the study.

Length Distributions:

Sampling was carried out at several locations and times using several gear types. Lengths were taken for all tagged fish and in most sampling events all fish were measured (Appendices A1 and A2). The length data were summarized by location, time of sampling, and gear type. To test whether there were any differences between sampling events, the length distributions were compared between locations for month and gear type where the data were available. If both electrofishing and hook and line gear were used in the same location and time, the length distributions for the two gear types were compared. A comparison of the length distributions of tags released and those recaptured within a sampling event was used to test the hypothesis of gear selectivity. In the Gulkana River sampling, this could only be done for tags released and recaptured during the electrofishing sampling events due to insufficient numbers recaptured in hook and line sampling events. For all of these comparisons, a Kolmogorov-Smirnov statistic (Sokal and Rohlf 1969) was used to compare the length distributions between the two groups at an alpha level of 0.05.

Age Composition and Mean Length-At-Age:

The age compositions of the Arctic grayling sampled at the weirs in Sourdough and Poplar Grove Creeks and during the mainstem Gulkana River electrofishing and hook and line surveys were estimated. Letting p_{hi} equal the estimated proportion of age class h in stratum i, the variance of p_{hi} was estimated by (Scheaffer et al. 1979):

$$V(\hat{p}_{hi}) = \hat{p}_{hi}(1-\hat{p}_{hi})/(n_{Ti}-1), \quad (5)$$

where n_{Ti} is the number of legible scales read from samples collected during stratum i.

Mean length-at-age was estimated by:

$$\bar{l}_a = \frac{\sum_{i=1}^{n_a} l_{ai}}{n_a} \quad (6)$$

where:

$\bar{l}_a$ = mean length at age a,

l_{ai} = length of i<u>th</u> fish at age i, and

n_a = number of fish at age a.

The variance of $\bar{l}_a$ was estimated as:

$$\text{Var } \bar{l}_a = 1/n_a(n_a-1)\sum_{i=1}^{n_a}(l_{ia}-\bar{l}_a)^2 \quad (7)$$

The hypothesis that the age compositions were independent, i.e. the same for electrofishing surveys in the Middle Fork and Sourdough reaches in the months June through August of 1987, was tested using a loglinear analysis. The TABLES module of the software program SYSTAT (Wilkinson 1988) was used for this analysis. Age compositions for the samples taken in the mainstem river during the 1986 float surveys in June, July, and August were compared using chi-square statistics to test the null hypothesis of independence between months. During 1987 and 1988, samples were taken for electrofishing and hook and line gear in the same sampling locations and times, and the age compositions between gear types were compared. In addition, age compositions were compared between the samples taken at the weirs in May and the mainstem river samples collected during June for 1986 and 1987. These analyses were carried out using the SAS FREQ procedure for analysis of contingency tables (SAS 1987).

Analysis of variance methods were used to test the hypothesis that there were no differences in mean length-at-age between locations and months of sampling and that there was no interaction between these two factors. The analysis was carried out separately for each age group using the SAS GLM procedure for general linear models (SAS 1987).

Growth increments:

Growth increments were calculated in millimeters for all recaptured grayling. Analysis of covariance was used to test the effect of two factors, number of months at large and month of release, with length at first release as a covariate. The SAS procedure GLM was used for this analysis (SAS 1987).

RESULTS

Tagging

A total of 2,245 Arctic grayling (2,194 adults and 51 juveniles) were tagged and released in Poplar Grove Creek from 18 May through 20 May 1986 (Appendices A1 and A2). Counts of upstream migrating Arctic grayling in Poplar Grove Creek during 1986 were not complete counts. During 1987, a total of 1,508 Arctic grayling 200 mm FL or longer were tagged and released in Sourdough Creek from 10 May through 17 May (Appendix A1). An additional 1,417 juvenile Arctic grayling were collected, indicating that Sourdough Creek may provide important summer habitat for juvenile Arctic grayling (Appendix A2). Counts of Arctic grayling migrating into Sourdough Creek during 1987 were not complete due to the initiation of upstream migration prior to weir installation and heavy ice flows which prevented continuous operation of the weir during the migration period. No sampling was conducted in Poplar Grove Creek during 1987 due to insufficient flow which prevented fish from migrating upstream. A complete count of Arctic grayling migrating into Poplar Grove Creek during the period of weir operation was conducted during 1988. A total of 4,703 Arctic grayling 200 mm FL or longer were tagged and released in Poplar Grove Creek from 10 May through 22 May 1988 (Appendix A1). An additional 357 juvenile grayling were captured in Poplar Grove Creek during the 1988 weir operation (Appendix A2). High water conditions prevented the operation of a weir in Sourdough Creek during 1988.

A total of 9,343 Arctic grayling were tagged and released in the Gulkana River during the 1986, 1987, and 1988 float and electrofishing surveys (Appendix A1 and A2). Most of these fish (98.1%) were captured in the Sourdough or Middle Fork reaches, the areas where most of the sampling effort was directed.

Intrastream Migration

The majority of the recoveries of Arctic grayling were made in the same reach where the fish were first released (Figure 2). Of the 18,808 Arctic grayling tagged and released during the 1986, 1987, and 1988 tagging efforts, 794 (4.2%) recaptures were recorded during sampling in the mainstem Gulkana River. Of these recaptures, 340 (43.9%) were recorded in the same area of release and during the same survey period, while 298 (36.5%) were recaptured in the same area during later surveys, and 156 (20.5%) were recaptured in areas other than the site of release (Figure 2). Of the 156 grayling recaptured at sites other than the area of release, 99 (63.5%) had traveled upstream before recapture, while 57 (36.5%) had moved downstream. Most of the downstream migration was observed for fish which had been tagged in the Middle Fork reach during the summer and were then recaptured in the Sourdough reach during the fall

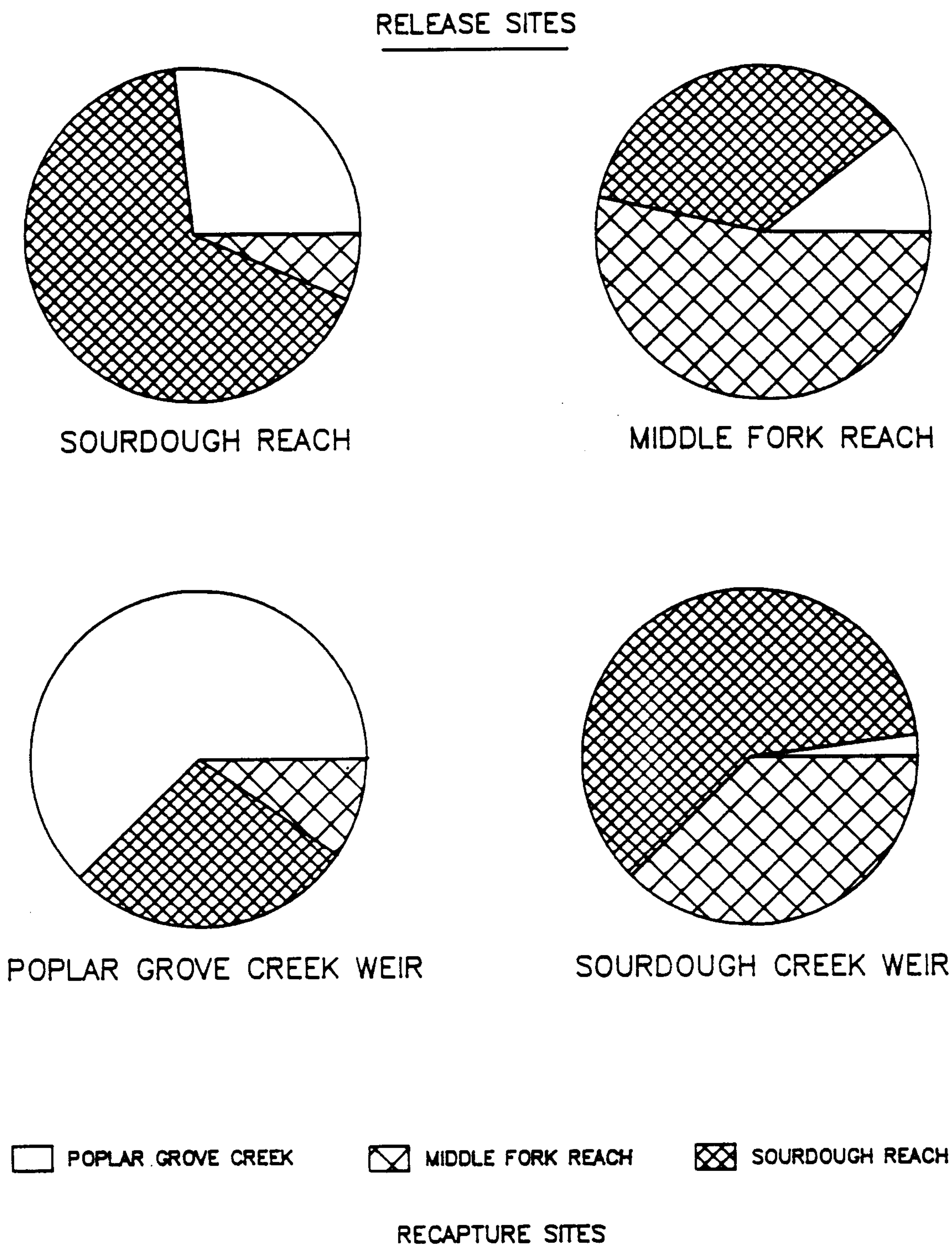

Figure 2. Percent of total recapture of tagged Arctic grayling by recapture reach for each release site in the Gulkana River during 1986, 1987, and 1988.

sampling. The greatest migration distance recorded for Gulkana River tagged Arctic grayling (85 km) was for fish which had migrated between Poplar Grove Creek and the outlet of Paxson Lake (Figure 1).

One hundred twenty-eight (128) of the 2,245 Arctic grayling tagged and released in Poplar Grove Creek during 1986 were recaptured during subsequent surveys (Table 3). Ninety-six (96) of these recaptures (75.0%) were recorded at the Poplar Grove Creek weir during 1988 (Figure 2). The remaining recoveries were recorded from Paxson Lake downstream to the mouth of Poplar Grove Creek (Figure 2). While Poplar Grove Creek tags were recovered in all of the mainstem river survey areas, no recoveries of grayling tagged in Poplar Grove Creek during 1986 were made at the Sourdough Creek weir during 1987. During 1988, 28 of the 4,711 grayling tagged at the Poplar Grove Creek weir were recaptured during the mainstem river surveys (Table 3).

Of the 1,584 Arctic grayling tagged and released in Sourdough Creek during 1987, 91 (5.7%) were later recaptured during the float and electrofishing surveys in the Gulkana River in 1987 and 1988, and 2 (0.1%) were recaptured at Poplar Grove Creek weir in 1988 (Table 3). Arctic grayling tagged in Sourdough Creek redistributed into the Gulkana River following spawning and were recovered in the Sourdough and Middle Fork reaches. The largest number of recoveries (58 or 63.7%) were made in the Sourdough reach (Figure 2).

Anglers returned tags from 153 Arctic grayling in the Gulkana River during the 1987 and 1988 sport fisheries. Twelve of the tag recoveries were from fish released during 1986, 102 were from fish tagged in 1987, and 39 were from fish tagged in 1988. Anglers reported tag recaptures from 11.3 km above the mouth of the Gulkana River upstream to the head of Paxson Lake. In addition, recoveries were reported in Poplar Grove Creek, Coleman Creek (Mile 135 of the Richardson Highway), Sourdough Creek, and Haggard Creek (a tributary to Sourdough Creek). No recoveries were reported outside of the Gulkana River drainage.

<u>Tag Ratios by Release and Recovery</u>

Analysis of the ratios of tagged-to-untagged fish was only possible for the 1987 tagging data in the Gulkana River, as there were insufficient numbers recovered in the 1986 and 1988 seasons (Table 3). In 1987, tags released at the Sourdough Creek weir in May and in the Sourdough and Middle Fork reaches of the river in June were recovered in subsequent months both in the Sourdough and Middle Fork reaches (Table 3). The results of the loglinear analysis were different for each of these three releases (Table 4). In all cases, the models chosen included interaction terms so the null hypothesis of independence was rejected in all cases; that is, the rate of tag recovery was not independent of time and location. However, the interaction terms included in the final models were different in each of the three cases. In all cases, a month-location interaction was included in the model to control for the unequal sampling effort over time and location. For the Sourdough Creek weir release and the Middle Fork June release, a second interaction term was included. However, this was not the same for the two releases. An interaction was modelled between tag presence and month of recovery for the Sourdough Creek weir release, while for the Middle Fork release, the interaction was

Table 3. Gulkana River Arctic grayling tagging experiments, 1986 through 1988, with number released with tags, number examined for tags, and number of recaptures[a] by site and sampling period.

		1986				1987										1988			
		Paxson to Sourdough				SD Weir[b]	Sourdough Reach				Middle Fork Reach					PG Weir[c]	Other		
															1987				GRAND
Release	Number	June	July	August	Total	May	June	July	Aug/Sep	Total	June	July	August	Total	Total	May	June-Sep	Total	TOTAL
Year Site	Released	n^d = 546	423	935	1,904	1,515	1,168	338	2,542	5,563	404	1,873	441	2,718	8,281	4,898	1,135	6,033	16,218
1986 PG Weir[c]	2,245	3	2	10	15	0	7	4	1	12	0	4	0	4	16	96	1	97	128
June	546		3	0	3	1	1	0	5	7	2	5	1	8	15	2	2	4	22
July	423			5	5	1	0	0	2	3	0	0	0	0	3	1	0	1	9
August	1,018					1	2	1	3	7	0	0	0	0	7	2	1	3	10
1987 SD Weir[b]	1,584						30	4	17	51	5	20	4	29	80	2	11	13	93
<u>Sourdough Reach</u>																			
June	1,143							32	40	72		9	3	12	84	6	6	12	96
July	338								10	10			0	0	10	0	0	0	10
Aug/Sept	2,534															62	25	87	87
<u>Middle Fork Reach</u>																			
June	396							1	3	4		30	6	36	40	2	0	2	42
July	1,866							2	27	29			21	21	50	12	5	17	67
August	438								8	8					8	1	0	1	9
1988 PG Weir[c]	4,906																28	28	28
Total	17,437	3	5	15	23	3	40	44	116	203	7	68	35	110	313	186	79	265	601

[a] Does not include multiple recaptures during a single sampling event, tags recaptured during the sampling event they were initially released in, or fish released in the mainstem river downstream of the Sourdough reach.

[b] Sourdough Creek Weir.

[c] Poplar Grove Creek Weir.

[d] Sample size.

Table 4. Results of loglinear analysis of the 1987 Gulkana River Arctic grayling tagging data.

Release	Model[a]	Chi-square	df	P-value
Sourdough Weir, May	T+L+M+TM+ML	2.73	3	0.436
Sourdough Reach, June	T+L+M+TL+TM+ML	6.88	1	<0.001
Middle Fork Reach, June	T+L+M+TL+ML	0.82	2	0.665

[a] T = presence of tag
L = location of recovery
M = month of recovery
TL = interaction between tag status and location
TM = interaction between tag status and month
ML = interaction between month and location, controlling for unequal sample sizes

between tag presence and location of recovery (Table 4). The only model chosen for the Sourdough reach tagging included all two-way interactions, between tag presence, and location and month of recovery. This model, however, did not fit the data adequately, as it had a p-value of less than 0.001.

Since there was interaction in the models chosen, the recovery of tags was not independent of location and time, i.e. the tagged-to-untagged ratios differed significantly. The interpretation of these results is most easily accomplished by an examination of odds ratios (Table 5). The odds ratios are partial odds ratios, that is each odds ratio was calculated for two of the variables while holding the third constant, or while conditioning on the third variable. For instance, the first set of odds ratios represent the ratio of tagged-to-untagged grayling caught in the Sourdough reach versus the ratio for grayling caught in the Middle Fork reach. This is conditioned on month, i.e. the odds ratios are calculated separately for each month. Table 5 shows both the odds ratios estimated from the loglinear model, and also the odds ratios calculated from observed cell frequencies.

The model chosen for the Sourdough Creek release data shows independence between presence of tags and location of recovery. The odds ratios predicted by the model for tag presence and location were equal to one, within each month and for all months combined (Table 5). There were differences observed for the tagging ratios between the two reaches in June through August for grayling sampled in the Sourdough and Middle Fork reaches. However, the interaction between tag presence and time of recovery was described by the odds ratios, which were all larger than one (Table 5). For example, the tagged-to-untagged ratio was twice as high in June than in July (θ = 2.1) and three times higher in June than in August (θ = 3.2) (Table 5). The biological interpretation of these results is that the fish tagged at the Sourdough Creek weir were more concentrated during June when the ratios of tagged-to-untagged fish were highest.

For the June Middle Fork release, there was conditional independence between tag presence and time of recovery, i.e. there was no interaction. The ratios of tagged-to-untagged grayling were not significantly different for July versus August within each of the recovery reaches, but this was not true for the reaches combined. There was an interaction term modelled for tag status and location of recovery. The rate of recapture of a fish tagged in the Middle Fork reach was 12 times higher in the Middle Fork reach compared to the Sourdough reach (θ = 0.09). The observed odds ratios were close to the predicted values (Table 5) as were the predicted frequencies (Table 6). The grayling tagged in Middle Fork reach in June were apparently not leaving the area but being recaptured in the same reach throughout July and August. Similar results were obtained for a July release in the Middle Fork reach when 1,849 grayling were tagged (Table 6). A chi-square test for independence comparing the tagged-to-untagged ratios in the August recoveries between the Sourdough and Middle Fork reaches was significant ($p < 0.001$), with only 1% being recaptured in the Sourdough reach compared to a 5% recapture rate in the Middle Fork reach (θ = 0.21).

No model could be chosen for the recoveries of tags released in June in the Sourdough reach (Table 4). Comparison of the estimated odds ratios for the

Table 5. Odds ratios for tagged-to-untagged ratios using estimated and observed frequencies for Gulkana River Arctic grayling tagging data, 1987.

A. Sourdough Creek Weir Release

Tag vs Untagged and:		Conditioned on: June	July	August	Combined
Sourdough Reach vs Middle Fork Reach	Model	1.00	1.00	1.00	1.00
	Obs.	2.08	1.10	0.73	1.17
		Sourdough	Middle Fork		Combined
June vs July	Model	2.09	2.09		2.09
	Obs.	2.21	1.16		2.09
June vs August	Model	3.22	3.22		3.22
	Obs.	3.92	1.38		3.22
July vs August	Model	1.54	1.54		1.56
	Obs.	1.77	1.18		1.56

B. Sourdough Reach June Release

		July	August	Combined
Sourdough Reach vs Middle Fork Reach	Model	15.27	15.27	4.87
	Obs.	21.45	2.32	4.87
		Sourdough	Middle Fork	Combined
July vs August	Model	5.60	5.60	1.30
	Obs.	6.53	0.71	1.30

C. Middle Fork Reach June Release

		July	August	Combined
Sourdough Reach vs Middle Fork Reach	Model	0.09	0.09	0.09
	Obs.	0.18	0.08	0.09
		Sourdough	Middle Fork	Combined
July vs August	Model	1.00	1.00	3.90
	Obs.	2.51	1.18	4.72

Table 6. Gulkana River Arctic grayling tagging experiments, 1986 through 1988, with number released with tags, number examined for tags, and percent of sample with tags[a] by site and sampling period.

			1986				1987										1988			
			Paxson to Sourdough				SD Weir[b]	Sourdough Reach				Middle Fork Reach				1987	PG Weir[c]	Other		GRAND
Year	Release Site	Number Released	June	July	August	Total	May	June	July	Aug/Sep	Total	June	July	August	Total	Total	May	June-Aug	Total	TOTAL
		n[d] =	546	423	935	1,904	1,515	1,168	338	2,542	5,563	404	1,873	441	2,718	8,281	4,898	1,135	6,033	16,218
1986	PG Weir[c]	2,245	0.55	0.47	1.07	0.79	0.00	0.60	1.18	0.04	0.22	0.00	0.21	0.00	0.15	0.19	1.96	0.09	1.61	0.79
	June	546		0.71	0.00	0.16	0.07	0.09	0.00	0.20	0.13	0.50	0.27	0.23	0.29	0.18	0.04	0.18	0.07	0.14
	July	423			0.53	0.26	0.07	0.00	0.00	0.08	0.05	0.00	0.00	0.00	0.00	0.04	0.02	0.00	0.02	0.06
	August	1,018					0.07	0.17	0.30	0.12	0.13	0.00	0.00	0.00	0.00	0.08	0.04	0.09	0.05	0.06
1987	SD Weir[b]	1,584						2.57	1.18	0.67	0.92	1.24	1.07	0.91	1.07	0.97	0.04	0.97	0.22	0.57
	<u>Sourdough Reach</u>																			
	June	1,143							9.47	1.57	1.29		0.48	0.68	0.44	1.01	0.12	0.53	0.20	0.59
	July	338								0.39	0.18			0.00	0.00	0.12	0.00	0.00	0.00	0.06
	Aug/Sept	2,534															1.27	2.20	1.44	0.54
	<u>Middle Fork Reach</u>																			
	June	396							0.30	0.12	0.07		1.60	1.36	1.32	0.48	0.04	0.00	0.03	0.26
	July	1,866							0.59	1.06	0.52			4.76	0.77	0.60	0.24	0.44	0.28	0.41
	August	438								0.31	0.14					0.10	0.02	0.00	0.02	0.06
1988	PG Weir[c]	4,906																2.47	0.46	0.17
	Total	17,437	0.55	1.18	1.60	1.21	0.20	3.42	13.02	4.56	3.65	1.73	3.63	7.94	4.05	3.78	3.80	6.96	4.39	3.71

[a] Does not include multiple recaptures during a single sampling event, tags recaptured during the sampling event they were initially released in, or fish released in the mainstem river downstream of the Sourdough reach.

[b] Sourdough Creek Weir.

[c] Poplar Grove Creek Weir.

[d] Sample size.

model with all interactions to those calculated using the observed frequencies (Table 5) shows large discrepancies. This model estimated that the capture probability for this release was 15 times higher in the Sourdough reach compared to the Middle Fork reach in both July and August. However, while the observed ratio was 21 for July, it decreased to only 2 for August. Similarly, the model estimated that the capture probabilities were 5.6 times higher in July than in August. However, while the observed was close to this number in the Sourdough reach (6.5 times more tags taken in July compared to August), it fell to 0.7 in the Middle Fork reach, i.e. the ratio in the Middle Fork was 1.4 times higher in August compared to July (Table 7). These results suggest there was a higher rate of migration from the Sourdough reach upstream to the Middle Fork reach from June to August than could be accounted for by this type of loglinear model. Upon examination of the residuals for the predicted frequencies, the residual for recoveries in the Middle Fork in August stood out (Table 7). The model predicted less than one tag expected in Middle Fork, while the sampling actually took three tagged fish. In contrast, 337 grayling were tagged and released in the Sourdough reach in July, and of these, ten (3.0%) were recovered in August; all in the Sourdough reach (Tables 3 and 6). This indicates that by July and August, the upstream movement was no longer as strong as for the June releases.

In summary, tags released at the Sourdough Creek weir were eventually mixed throughout the study reach with most of the movement occurring during June. Similarly, the results for the Sourdough reach releases from June and July suggest that upstream migration was still occurring in June, but by July it was not as prevalent. Fish tagged in the upriver reaches in June and July and recaptured in July and August also did not exhibit significant movement during this period, although some downstream movement was exhibited. The study can not determine how the migration patterns developed during the fall months, nor can this study provide information on the actual migrational range of these populations of tagged fish outside of areas included in the study.

Abundance Estimators

Insufficient numbers of tagged grayling were recaptured in 1986 and 1988 to generate abundance estimates, but sufficient recoveries were made in 1987, both from releases at the Sourdough Creek weir in May and from releases made in the Sourdough and Middle Fork reaches in June and July (Table 3). There were twice as many tagged fish in the Sourdough reach in June compared to the Middle Fork reach, but by July the tag ratios were the same in the two areas (Table 5). Although the tag numbers were small and the differences were not significant (Tables 4 and 5), the indications are that in June the grayling were still migrating, while in July they were stationary, particularly in the Middle Fork reach. The fish tagged at the weir moved throughout the study area, and in July, tagged-to-untagged ratios were equal in the Sourdough and Middle Fork reaches. Given this, a population estimate generated from these data (Table 8) represents the total abundance of adult grayling. The estimates were 106,000 and 138,500 adult grayling for the Sourdough and Middle Fork recaptures respectively, and 137,500 adult grayling for the combined data. There is, however, no information available to define the geographic bounds of this estimate.

Table 7. Observed and predicted frequencies of tagged and untagged Arctic grayling by month and location for each release group with standardized residuals for loglinear analysis of 1987 Gulkana River Arctic grayling tagging data.

Release Location	Recovery Location	Recovery Month	Tagged Obs.	Tagged Pred.	Tagged Resid.	Untagged Obs.	Untagged Pred.	Untagged Resid.
Sourdough Creek Weir	Sourdough	June	30	26	0.77	1138	1142	-0.12
		July	4	4	-0.17	335	335	0.02
		August	17	13	-0.22	2528	2527	0.02
	Middle Fork	June	5	9	-1.31	395	392	0.20
		July	20	20	-0.07	1857	1857	0.01
		August	4	3	0.52	435	436	-0.04
Sourdough Reach, June	Sourdough	July	32	29	0.47	307	309	-0.14
		August	40	42	-0.39	2505	2502	0.05
	Middle Fork	July	9	11	-0.74	1852	1849	0.06
		August	3	0	3.60	436	438	-0.12
Middle Fork	Sourdough	July	1	0	0.77	338	338	-0.03
		August	3	3	-0.28	2542	2541	-0.01
	Middle Fork	July	30	29	0.16	1831	1832	-0.02
		August	6	7	-0.33	433	432	0.04

Table 8. Population estimates for Arctic grayling in the Gulkana River during 1987.

A. Sourdough Creek Weir Tag Release:

Recovery Event	Abundance	Standard Error
Sourdough Reach		
July	106,000	43,000
Middle Fork Reach		
July	138,500	29,000
July Combined	137,500	26,600

B. Inriver June Releases and July Recoveries:

	Recovery		
Release	Sourdough	Middle Fork	Released
Sourdough Reach	32	9	1,143
Middle Fork Reach	1	30	396
Tags	33	39	
Untagged	305	1,834	

Strata	Abundance	95% Confidence Intervals	Relative Precision
Sourdough Reach	9,854	6,209-13,500	36.9%
Middle Fork Reach	22,234	13,549-30,918	39.0%
Total	32,088	23,313-40,863	27.0%

Assuming that the grayling remain stationary in the mid-summer period and that Sourdough Creek weir fish distribute evenly only throughout the mainstem river, this would then represent the population for the mainstem of the Gulkana River. If Sourdough Creek weir fish move into the West and Middle Fork tributaries in even proportions, as they are distributed in the mainstem, then this is a drainage-wide estimate. Any other type of movement between the mainstem and the two major tributaries (West Fork and Middle Fork) will bias the estimate.

A second population estimate can be made using the stratified Petersen estimator (Table 8) with the Sourdough and Middle Fork reaches representing two strata, with releases in June and recoveries in July. This allows for the migrational movements between the two strata, i.e. within the mainstem area including the Sourdough and Middle Fork reaches. This estimate gave a total of nearly 33,000 adult fish in the two strata. However, the stratified Petersen estimator assumes a closed population with no emigration from or immigration into the strata. Again, the lack of information available on migration patterns into the tributaries or to areas below the Sourdough reach is a problem as this major assumption of the estimator cannot be tested.

These abundance estimates include all fish sampled, without adjusting for growth recruitment. If there is growth, which would seem reasonable as tags were placed in May and June, and recoveries were made in June through August, then there will be an overestimate of the abundance. However, due to small sample sizes, it was not possible to assess the amount of growth recruitment that had occurred.

Length Distributions

Mean lengths increased over time for each location and month, except in the Middle Fork reach where the mean length was actually larger in June compared to July in all 3 years (Table 9). This was a significant difference in all cases (Table 10). The mean lengths were significantly larger in all months in the Middle Fork reach compared to the Sourdough reach (Table 10). In 1987, recaptures of fish released at the Sourdough Creek weir and in the Sourdough reach in June were made both in the Sourdough and Middle Fork reaches in June, July, and August. Although sample sizes were small, the length distributions (Table 11) were significantly different for the June recovery of the weir release and the July recovery of the June Sourdough reach release (Table 12).

The mean lengths of Arctic grayling were larger in electrofishing gear samples compared to hook and line samples within a given month and location and the length distributions were significantly different (Table 10). The selectivity of electrofishing gear was further indicated by comparing the length distributions of grayling released and recaptured over a series of days within a single electrofishing sampling event (Table 12). In all cases where sufficient numbers of recaptures were made, the average length of recaptured grayling was larger than the mean length at release (Table 12) and the length distributions were significantly different (Table 12). The gear selectivity of electrofishing suggests that release and recovery samples would have to be stratified by length class for any future population estimates.

Table 9. Gulkana River Arctic grayling mean lengths by sampling event[a], 1986 through 1988.

Sampling Site	Sampling Dates	Capture Technique	Number Sampled	Mean Length	Standard Error
1986					
Poplar Grove Creek	5/14-5/17	Dipnet	850	252	1.04
Poplar Grove Creek	5/18-5/20	Weir	2,242	234	0.46
Paxson to Sourdough	6/27-7/1	Hook&Line	557	286	1.63
Paxson to Sourdough	7/16-7/21	Hook&Line	415	278	1.98
Paxson to Sourdough	7/28, 7/30, 8/9, 8/11	Hook&Line	95	273	4.12
Sourdough Reach	8/18-8/20	Electro	1,198	234	1.95
1987					
Sourdough Creek	5/10-5/17	Weir	2,932	208	0.97
Poplar Grove Mouth	6/12-6/13	Electro	204	229	2.50
Paxson Lake Outlet	6/20	Electro	34	305	4.21
Sourdough Reach	6/22-6/25	Electro	1,096	261	1.32
Middle Fork Reach	6/27-6/29	Electro	367	301	2.00
Paxson Lake Outlet	7/14-7/15, 7/24	Electro	60	296	4.91
Middle Fork Reach	7/16-7/19	Hook&Line	385	287	2.70
Middle Fork Reach	7/16-7/24	Electro	1,504	289	0.96
Sourdough Reach	7/25-7/29	Electro	443	260	2.26
Middle Fork Reach	8/21-8/24	Electro	220	298	2.83
Middle Fork Reach	8/25-8/26	Hook&Line	225	291	2.23
Sourdough Reach	8/10, 8/28-9/3	Electro	1,179	271	1.37
Sourdough Reach	9/15-9/19	Electro	1,647	292	0.91
1988					
Sourdough Creek	5/5, 5/9	Hook&Line	81	292	3.90
Poplar Grove Creek	5/10-5/22	Weir	4,994	264	0.51
Sourdough Reach	6/23	Electro	11	291	9.18
Middle Fork Reach	6/23-6/28	Hook&Line	172	295	3.02
Middle Fork Reach	7/23-7/27	Both[b]	83	277	4.74
Sourdough Reach	8/5-8/6, 8/24-8/27	Electro	184	232	3.19
Middle Fork Reach	8/26, 8/28	Both[b]	34	305	7.38
Sourdough Reach	9/13-9/17	Electro	794	245	1.78
Middle Fork Reach	9/20	Electro	13	338	7.11
Gulkana Mouth	9/24-9/25	Both[b]	22	251	9.29

[a] Data include all fish measured including multiple recaptures.

[b] Electrofishing and Hook & Line.

Table 10. Comparison of length distributions[a] of Arctic grayling sampled in the Gulkana River during 1986, 1987, and 1988.

Comparison	Sampling Events	Length (n)		P-Value[b]
Between Gear Types in the Middle Fork Reach	1987	Electro	Hook&Line	
	July	289(1,564[c])	287(384)	.0002
	August	298(225)	291(220)	.0210
	1988			
	July	305(20)	268(63)	.0132
	August	321(13)	295((21)	.2031
Between Reaches for Electrofishing by Month, 1987		Middle Fork	Sourdough	
	June	301(401[c])	261(1,301[d])	.0001
	July	289(1,564[c])	260(443)	.0001
	August	298(220)	271(1,167)	.0001
Between June and July in the Middle Fork		June	July	
	1986	286(545)	278(416)	.0134
	1987[c]	301(401)	289(1,564)	.0001
	1988	295(172)	168(63)	.0043

[a] P-value less than 0.05 is considered significant.

[b] Includes Paxson Lake outlet and the Middle Fork reach.

[c] Includes the Sourdough reach and Poplar Grove Creek Mouth.

[d] Includes the Sourdough reach and Poplar Grove Creek Mouth.

Table 11. Comparison of length distribution[a] of recaptured Arctic grayling between recovery sites in the Gulkana River during 1987.

		Recapture Reach						
		Sourdough			Middle Fork			
Release Site	Recapture Month	Sample Size	Mean Length	SE[b]	Sample Size	Mean Length	SE[b]	P-Value[c]
Sourdough Creek Weir	June	25	256	5.89	5	322	9.55	.0097
	July	6	263	14.63	18	274	8.97	.5040
	August	18	268	6.26	4	275	7.77	.3860
Sourdough Reach June	July	47	292	6.00	7	312	5.00	.0442

a Standard Error.

b P-value less than 0.05 is considered significant.

c P-value less than 0.05 is considered significant.

Table 12. Comparison of length distributions[a] of released and recaptured Arctic grayling during the electrofishing sampling events, 1986 and 1987.

Year	Event	Number Released	Mean Length	Standard Error	Number Recaptured	Mean Length	Standard Error	P-Value[b]
1986	Sourdough - August	908	248	1.57	39	266	8.45	.0264
1987	Middle Fork - July	1,010	291	1.08	35	315	5.74	.0012
1987	Sourdough - July	290	265	2.24	38	283	7.02	.0813
	Sourdough - August	984	279	1.25	28	294	5.91	.0261
	Sourdough - September	1,361	291	0.96	135	302	3.14	.0044

[a] Kolmogorov-Smirnov test used to compare length distributions.

[b] P-value less than 0.05 is considered significant.

There was an increase in size of Arctic grayling from the downstream to upstream areas. This was most apparent when comparing 1987 electrofishing data for the Sourdough and Middle Fork study reaches by survey period (Figure 3). There was also an increase in mean length between sampling events within each reach indicating growth over the summer, with the exception of June in the Middle Fork reach as discussed earlier. The same trend is evident from recaptures of adult grayling released at the Sourdough Creek weir in May, where the mean length of five tagged fish recaptured in the Middle Fork reach in June is 322 mm compared to 256 mm in the Sourdough reach in the same month and 270 mm in the Middle Fork reach in July (Table 11). This would be explained by an earlier upstream movement of larger fish, as evidenced by the June Middle Fork recaptures of Sourdough Creek weir releases. Then as the season progressed, the smaller fish moved upstream and entered the Middle Fork reach sampling population causing a reduction in the calculated mean lengths during July for the study reach.

Growth Increments

A number of recaptures (n = 340) occurred within the same sampling event and the differences between length at release and recapture in this case can be defined as measurement error, which would be expected to equal zero. The mean error was in fact -1.5 mm (SE = 1) and was not significantly different from zero, but the error was found to have a negative correlation with length at release ($r = 0.22$), which although weak, was significantly different from zero ($p < 0.05$). Large fish tended to have a negative error more often than smaller fish (Figure 4).

There were 158 measured recaptures from 1986 releases and 460 recaptures from the 1987 releases. The results of the analysis of covariance for these two releases were that both main factors had a significant effect on growth, although month of release was only significant for 1987 releases at an alpha level of 0.05, while months at large and length at release had highly significant F-values for both releases (Table 13). Growth is negatively correlated with length at release and positively correlated with months at large as would be expected (Figure 5). The month of release had a negative affect as fish tagged late in the season exhibited little or no growth over the winter (2 mm, SE = 1 mm) compared to a fish at large for the same number of months, but tagged in the spring (21 mm, SE = 2 mm).

Age Composition and Mean Length-At-Age

Comparison of Age Composition:

Arctic grayling sampled in the Gulkana River and in Sourdough and Poplar Grove Creeks were from 0 through 7 years old, with age classes 3, 4, and 5 comprising the largest percentage of the fish sampled (Tables 14-20). All of the juvenile grayling sampled at the weirs in Sourdough Creek during 1987 and in Poplar Grove Creek during 1988 were age 2 or older. Ages 4, 5, and 6 comprised 88.7% of the grayling 250 mm fork length or longer collected at the Poplar Grove Creek weir in 1988 for which sex and age data were collected (Table 21). A portion of the age 3 grayling collected at the weir were

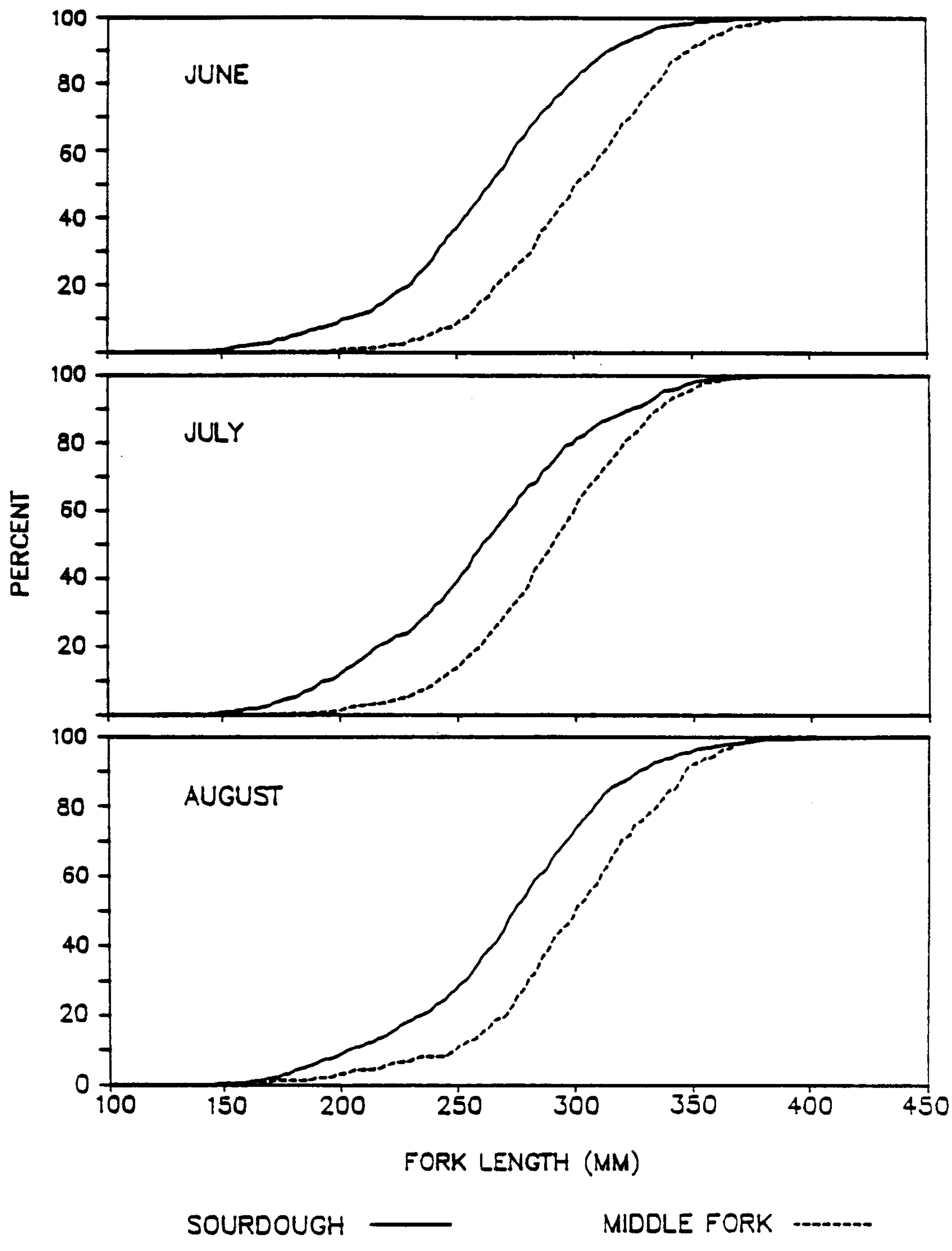

Figure 3. Comparison of the cumulative length frequency by sampling period for Arctic grayling collected by electrofishing in the Sourdough and Middle Fork study reaches of the Gulkana River, 1987.

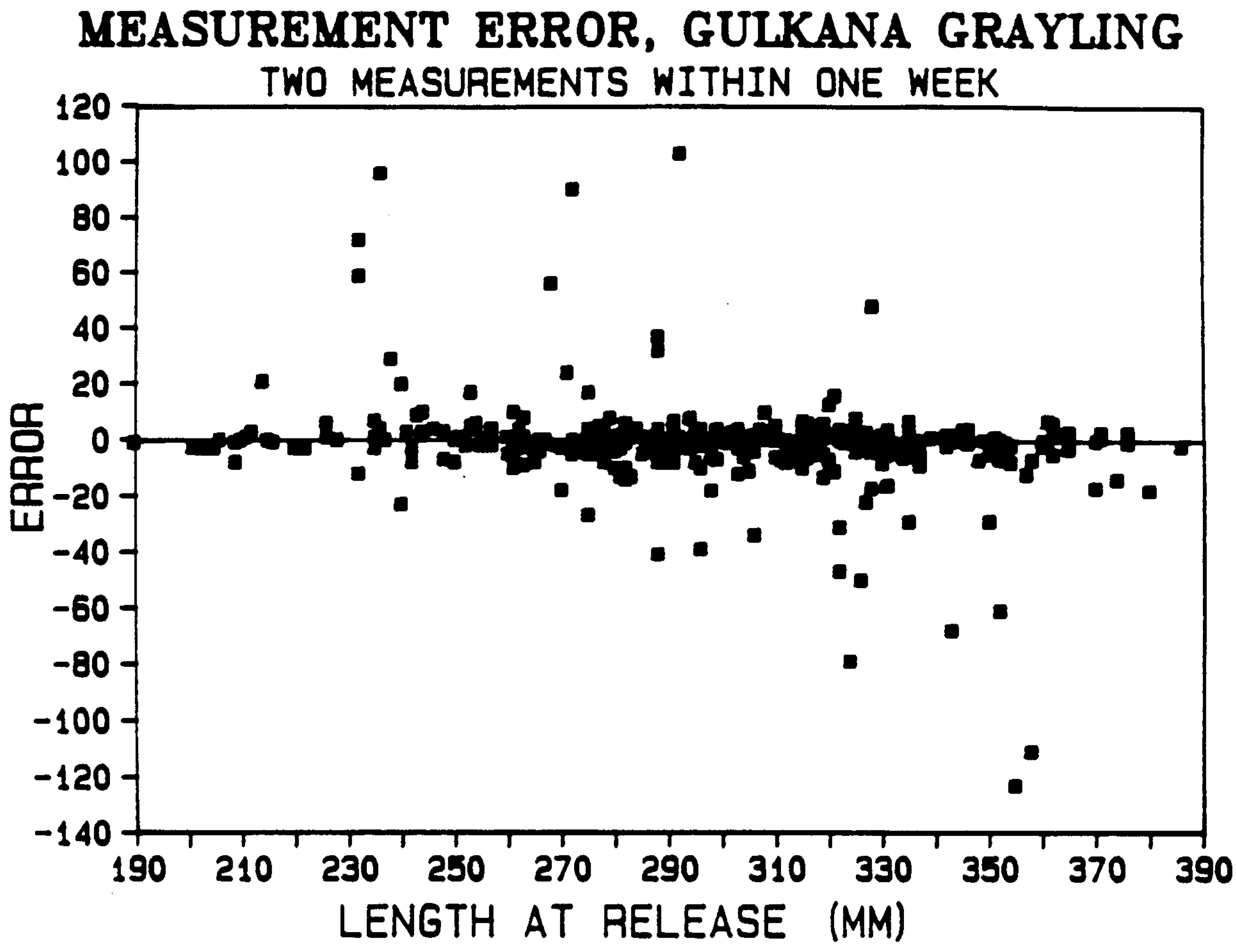

Figure 4. Error in measurement of Arctic grayling defined as difference in length from release to recapture within the same week.

Table 13. Results of ANOVA testing the effects of month of release and months at large on growth increment with length at release as a covariate.

Source	d.f.	MSE	F-Value	P-Value[a]
1986 Release				
Month Released	3	388.0	2.10	.1000
Months at Large	15	471.3	2.55	.0020
Interaction	6	344.0	1.86	.0900
Length at Release	1	7,488.9	40.55	.0001
Error	133	184.7		
1987 Release				
Month Released	4	685.7	2.86	.0200
Months at Large	12	1,284.3	5.35	.0001
Interaction	14	270.2	1.13	.3300
Length at Release	1	11,756.1	48.97	.0001
Error	429	240.0		

[a] P-value less than 0.05 is considered significant.

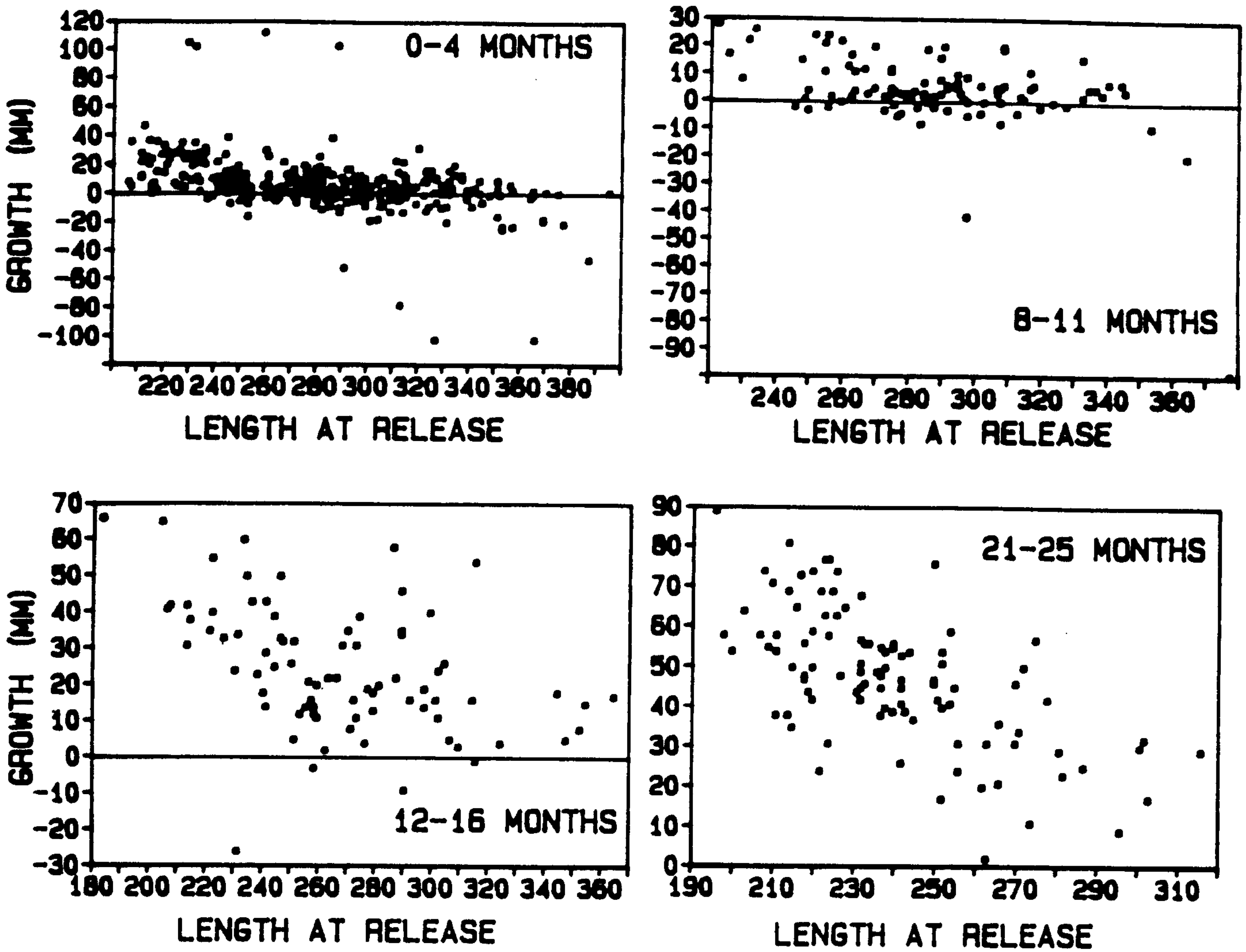

Figure 5. Growth increments for Arctic grayling in Gulkana River, 1986-88, by months at large.

Table 14. Age composition and length data for Arctic grayling collected in Poplar Grove Creek, 1986.

Parameter	Age Class 1	2	3	4	5	6	Total
Age Composition							
Percent	0.0	0.6	40.1	49.2	8.2	1.9	100.0
SE	---	0.4	2.6	2.6	1.4	0.7	---
Sample Size	0	2	146	179	30	7	364
Length Composition							
Mean	---	221	237	250	265	290	246
SE	---	2.8	1.5	1.4	4.4	6.7	1.1
Sample Size	0	2	146	179	30	7	364

Table 15. Age composition and length data for Arctic grayling collected in the Gulkana River, 1986.

	Age Class						
Parameter	1	2	3	4	5	6	Total
Age Composition							
Percent	12.0	11.3	27.1	30.2	15.7	3.7	100.0
SE	1.1	1.1	1.5	1.5	1.2	0.6	---
Sample Size	108	101	243	271	141	33	897
Length Composition							
Mean	144	211	257	284	318	339	259
SE	2.0	3.0	1.7	1.6	2.2	4.6	2.0
Sample Size	108	101	243	271	141	33	897

Table 16. Age composition and length data for Arctic grayling collected in Sourdough Creek, 1987.

Parameter	Age Class 1	2	3	4	5	6	Total
Age Composition							
Percent	0.0	14.8	29.2	34.8	16.2	5.0	100.0
SE	---	1.4	3.4	3.3	3.7	4.0	---
Sample Size	0	89	176	210	98	30	603
Length Composition							
Mean	---	176	224	253	290	332	243
SE	---	2.8	1.5	1.4	4.4	6.7	1.9
Sample Size	0	89	176	210	98	30	603

Table 17. Age composition and length data for Arctic grayling collected in the Sourdough reach of the Gulkana River, 1987.

Parameter	Age Class 1	2	3	4	5	6	Total
Age Composition							
Percent	7.3	16.4	28.9	31.9	13.7	1.8	100.0
SE	1.2	1.6	2.0	2.1	1.5	0.6	---
Sample Size	37	83	146	161	69	9	505
Length Composition							
Mean	169	215	261	283	312	341	262
SE	2.9	3.2	2.3	2.3	3.1	6.0	2.2
Sample Size	37	83	146	161	69	9	505

Table 18. Age composition and length data for Arctic grayling collected in the Middle Fork reach of the Gulkana River, 1987.

Parameter	Age Class						Total
	1	2	3	4	5	6	
Age Composition							
Percent	0.0	4.6	24.6	44.1	24.7	2.0	100.0
SE	---	0.7	1.5	1.8	1.5	0.5	---
Sample Size	0	37	196	352	197	16	798
Length Composition							
Mean	---	239	273	298	319	341	295
SE	---	6.2	1.9	1.6	2.0	4.6	1.3
Sample Size	0	37	196	352	197	16	798

Table 19. Age composition and length data for Arctic grayling collected in Poplar Grove Creek, 1988.

	Age Class						
Parameter	1	2	3	4	5	6	Total
Age Composition							
Percent	0.0	15.5	26.7	23.9	23.5	10.4	100.0
SE	---	1.5	1.9	1.8	1.8	1.3	---
Sample Size	0	88	152	136	134	59	569
Length Composition							
Mean	---	194	227	269	290	318	256
SE	---	2.5	1.9	1.9	2.3	3.8	1.9
Sample Size	0	88	152	136	134	59	569

Table 20. Age composition and length data for Arctic grayling collected in the Gulkana River, 1988.[a]

	Age Class							
Parameter	0	1	2	3	4	5	6	Total
Age Composition								
Percent	0.8	10.7	31.7	29.5	13.4	9.2	4.7	100.0
SE	0.4	1.3	1.9	1.9	1.4	1.2	0.9	---
Sample Size	5	64	190	177	80	55	28	599
Length Composition								
Mean	105	186	223	255	290	309	338	250
SE	5.6	3.3	1.6	2.1	2.9	3.5	6.0	2.0
Sample Size	5	64	190	177	80	55	28	599

[a] Sampling was conducted during August and September.

Table 21. Age composition, sex ratio, and length data for Arctic grayling collected at the Poplar Grove Creek weir during May, 1988.

		Age Class						
Sex	Parameter	2	3	4	5	6	7	Total
Age Composition[a]								
Male	Percent	0.0	3.9	16.0	25.5	10.8	3.5	59.7
	SE	---	1.3	2.4	2.9	2.0	1.3	3.2
	Sample Size	0	9	37	59	25	8	138
Female	Percent	0.0	2.6	13.4	16.9	6.1	1.3	40.3
	SE	---	1.0	2.2	2.5	1.6	0.7	3.2
	Sample Size	0	6	31	39	14	3	93
Combined	Percent	0.0	6.5	29.4	42.4	16.9	4.8	100.0
	SE	---	1.6	3.0	3.3	2.5	1.4	---
	Sample Size	0	15	68	98	39	11	231
Length Composition[b]								
Mean		194	227	269	290	312	345	256
SE		3	2	2	2	3	10	2
Sample Size		88	152	136	134	48	11	569

[a] Age composition and sex ratio data is for grayling 250 mm or larger.
[b] Length composition data is for all fish aged.

observed to be sexually mature which is younger than that reported for other Alaska river systems (Ridder 1989, Tack 1980).

During 1986 and 1987, there was an increase in the proportion of age 2 and age 3 grayling in the samples from the June sampling to the July and August sampling, and ages 4 and 5 decreased in proportional representation during the same period (Figures 6 and 7). The model fit in the loglinear analysis for the 1987 data was one where all two-way interactions were included ($G = 10.6$, $df = 8$, $p = 0.22$); i.e. age compositions were significantly different between locations and months. Examination of the frequencies predicted by the model for each month and location (Table 22) shows that while ages 2 and 3 increased and ages 4 and 5 decreased in both reaches, the younger age classes remained more heavily represented in the Sourdough reach and the older ages were more heavily represented in the Middle Fork reach. The observed frequencies were fairly close to the predicted, with the greatest residuals occurring for the June samples where the observed frequency of age 2 grayling is higher than the predicted in the Middle Fork reach (Figure 6) and the frequency of age 4 is lower than predicted.

In 1986, the age compositions were significantly different between months (Figure 6 and Table 21). The age composition found at the weirs in 1986 and 1987 (Figure 8) was significantly different from that in samples taken with electrofishing gear one month later (Table 23). In both years, the younger age classes were more numerous at the weirs (Figure 8). However, the test for independence was not rejected for the comparison between gear types in 1987 or 1988 (Figure 9), indicating that the age compositions are not significantly different between gear types (Table 23). However, sample sizes were small for this analysis.

These results may be due to gear selectivity and/or differences in age composition between time and area of sampling. Electrofishing is demonstrated to be selective for larger fish and the higher representation of younger fish at the weirs compared to the June mainstem samples can be explained in part by gear selectivity. The apparent increase in the abundance of the younger age classes over the summer could be explained by growth recruitment. There was, however, a difference within a given month between locations that can only be explained by real differences in age compositions. This is shown by the consistent presence of larger numbers of age 2 and 3 fish in the Sourdough reach compared to the Middle Fork reach in July and August (Figure 7).

Comparison of Mean Length-At-Age:

While age samples were collected in essentially all months of the summer and at all locations (Appendices A1 and A2), the most consistent sampling took place during the 1987 electrofishing surveys. The data from the electrofishing surveys for the Middle Fork and Sourdough reaches in June through August were included in the analysis of variance run for each age group 2 through 6. In most cases, the analyses gave significant differences between locations and between months, but no interaction between the two (Table 24). The exceptions were for age 6 data where no significant differences were found and the analysis for age 2 data which gave no significant differences between months.

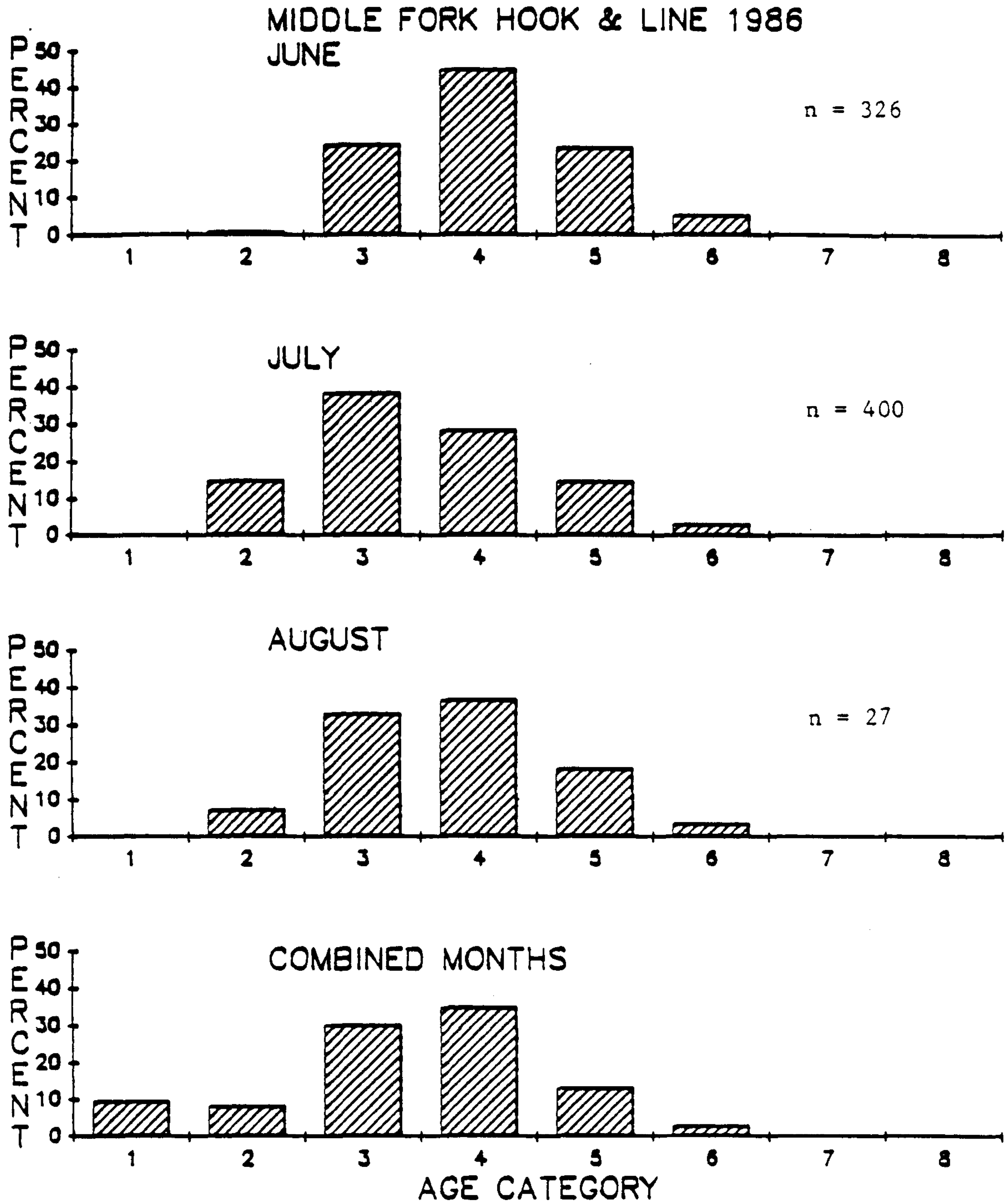

Figure 6. Age composition of Arctic grayling sampled by hook and line gear in the Middle Fork reach of the Gulkana River during 1986.

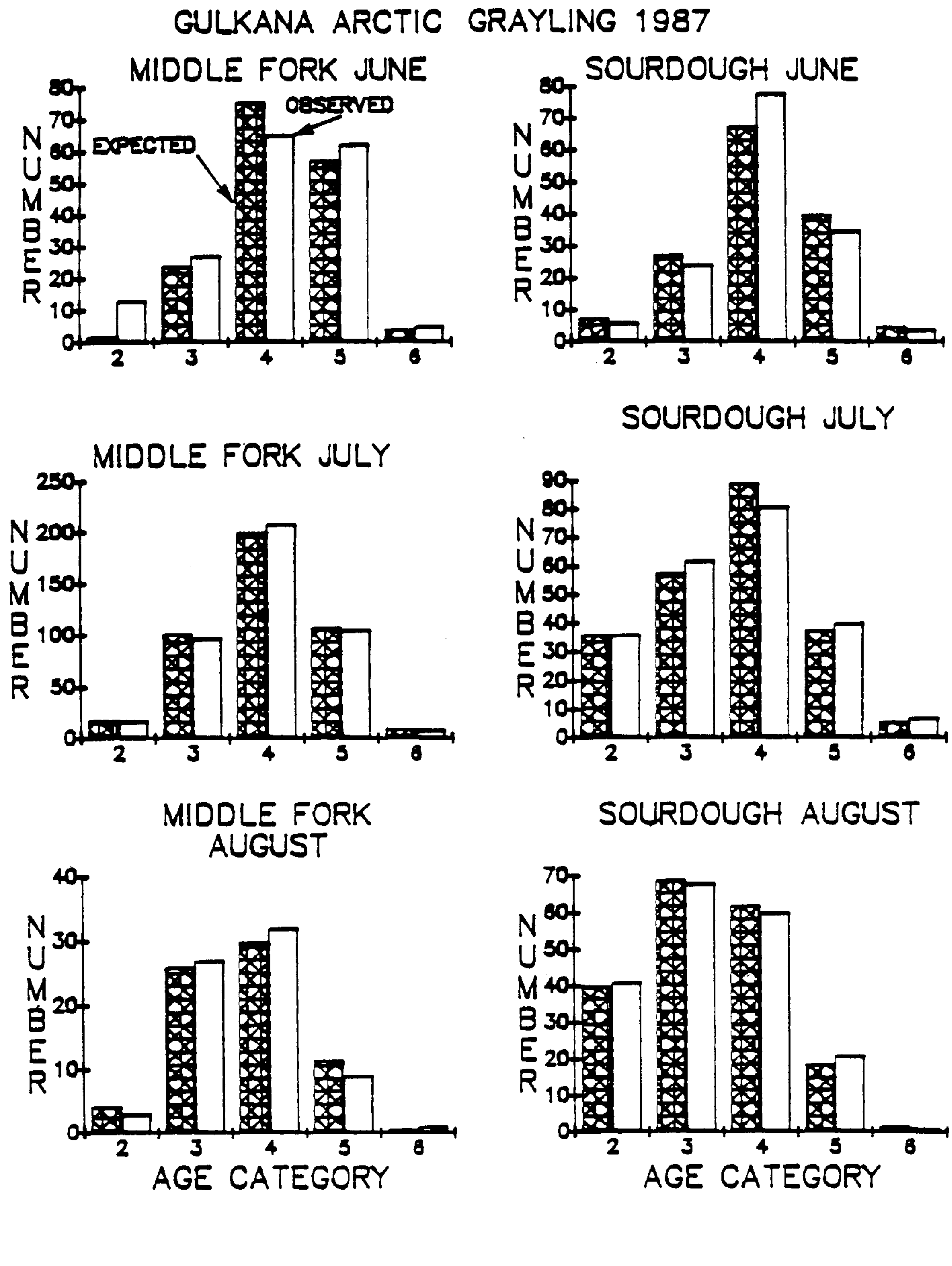

Figure 7. Age compositions of Arctic grayling sampled with electrofishing gear in the Gulkana River during 1987, with expected age compositions derived from loglinear analysis.

Table 22. Results of loglinear analyses to test association between age compositions and time and location for the 1987 Gulkana River electrofishing surveys.

$$\text{MODEL:} \quad \log m_{ijk} = \lambda_i^{A} + \lambda_j^{M} + \lambda_k^{L} + \lambda_{ij}^{AM} + \lambda_{ik}^{AL} + \lambda_{jk}^{ML} \quad ^{a}$$

Predicted Frequencies (%)

Month	Location	Age 2	3	4	5	6
June	Middle Fork	1.07	14.67	45.29	35.22	2.52
	Sourdough	4.94	18.52	46.00	20.37	3.34
July	Middle Fork	3.94	23.27	45.91	24.71	2.16
	Sourdough	15.86	25.57	39.50	16.59	2.49
August	Middle Fork	5.71	36.12	41.52	15.90	0.74
	Sourdough	20.88	36.12	32.51	9.71	0.77

[a] A = Age

M = Month

L = Location

m_{ijk} = number of grayling at age i in jth month and kth location

λ_i = model parameter for age

i = 1, 2, 3, 4, 5, or 6

j = 1, 2, 3

k = 1, 2

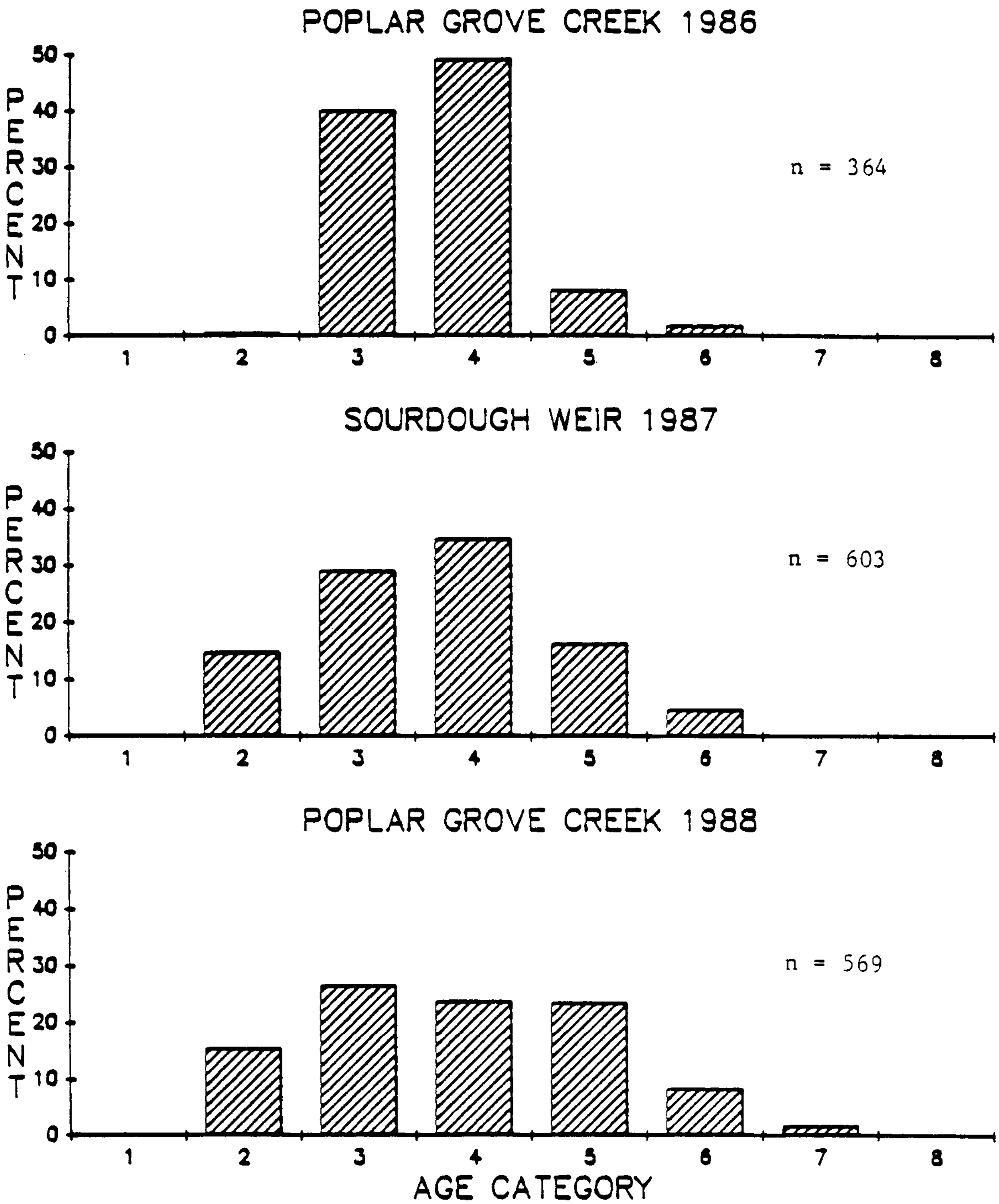

Figure 8. Age compositions of Arctic grayling collected at the Poplar Grove Creek (1986 and 1988) and Sourdough Creek (1987) weirs.

Table 23. Results of the chi-square tests for independence for age compositions for 1986, 1987, and 1988 Gulkana River Arctic grayling samples.

Year	Comparison	χ^2	d.f.	P-Value[a]	n
1986	Weir vs June Sample	46.8	4	<0.0001	690
1986	Between Months	76.2	8	<0.0001	753
1987	Weir vs June Sample	119.7	12	<0.0001	416
1987	Between Gear Types	6.0	4	0.2010	151
1988	Between Gear Types	4.0	4	0.4040	26

[a] P-value of less that 0.05 is considered significant.

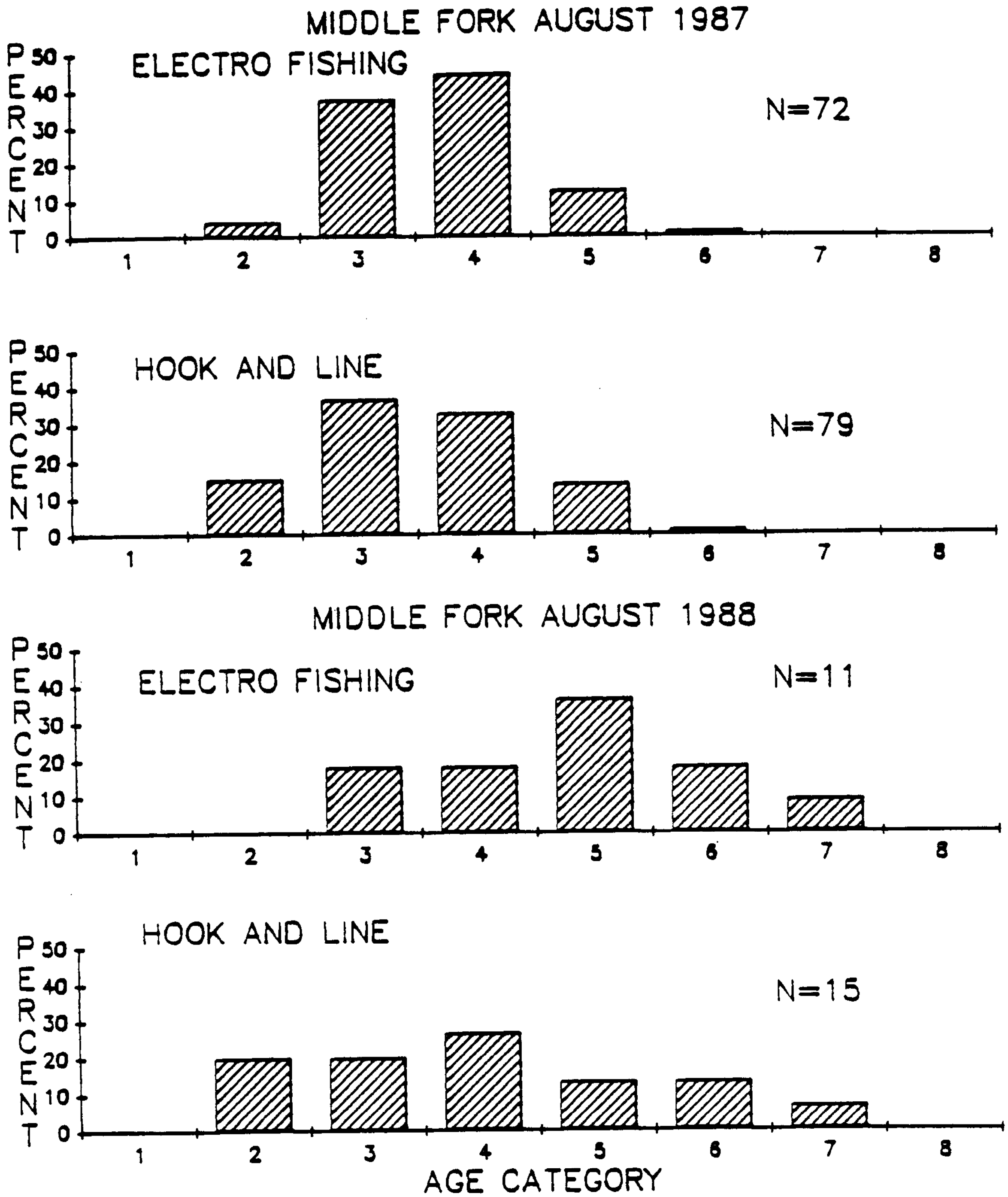

Figure 9. Age compositions of Arctic grayling sampled with electrofishing and hook and line gear in the Middle Fork reach of the Gulkana River during 1987.

Table 24. Results of ANOVA comparing the mean length-at-age for Gulkana River Arctic grayling, 1987.

1) Month / Location for Electrofishing

Age	P-Values[a]			Sample Size
	Month	Location	Interaction	
2	0.0926	0.0170	0.9830	106
3	0.0001	0.0001	0.4281	305
4	0.0001	0.0001	0.9712	524
5	0.0013	0.0005	0.2674	272
6	0.7873	0.9220	0.4420	26

2) Between Gear Types - Middle Fork, August

Source	P Value[a]
Age	0.0001
Gear	0.2441
Age - Gear	0.0894

[a] P-value of less that 0.05 is considered significant.

These were the two age groups with the smallest sample sizes. Mean length-at-age was consistently larger in the Middle Fork reach (Figure 10).

During 1987, samples were taken with both hook and line and electrofishing gear in August in the Middle Fork reach. The mean length-at-age was apparently smaller for the older ages in the hook and line samples (Figure 11). An analysis of variance did not show significant interaction between gear and age for these data, nor did it show significant differences between gear types (Table 24). However, sample sizes were small, and the p-value for the interaction was close to the significance level of $p = 0.05$. Larger sample sizes could possibly have given different results. Further sampling is needed to test this trend.

DISCUSSION

The data collected during 1986, 1987, and 1988 show that Arctic grayling in the Gulkana River undergo extensive interstream and intrastream migrations. The interstream migrations were observed for Arctic grayling which spawned in Sourdough and Poplar Grove Creeks and later redistributed throughout the Gulkana River following spawning. This was also observed for Arctic grayling tagged and released during 1986 in Poplar Grove Creek (Roth and Delaney 1987). The recoveries of tagged fish by anglers indicate that these migrations make an important contribution to the Gulkana River sport fishery. The migration patterns observed for Arctic grayling in the Gulkana River drainage included movement to spawning areas in the spring, the redistribution of fish to mainstem summer feeding areas, and the spatial distribution of fish by size and age during the summer with larger fish found in upstream areas. These results are similar to the patterns reported for grayling by Tack (1980) and Ridder (1989). Although we did not survey the spawning tributaries after the upstream spawning migration was complete, the lack of recoveries or observations of age 0 grayling in the mainstem river indicates that this age class spends its first summer in the spawning tributaries. The recovery of age 1 fish during the summer mainstem surveys indicates that the outmigration of age 0 fish from the spawning tributaries probably occurred during the previous fall.

Arctic grayling tagged in Sourdough Creek during May showed extensive interstream and intrastream migrations following tagging. Although tagged-to-untagged ratios were not significantly different in the two study reaches, the recaptures of large fish in the Middle Fork reach in June indicate that there were differential migration rates for different size classes. The consistent difference in mean length between the upstream and downstream sites within the mainstem river suggests that size segregation continued through the summer. By July and August, less movement was observed in both reaches of fish tagged at the weir and of fish tagged in the mainstem river. However, the tagged-to-untagged ratios decreased in all reaches over the summer, with highest availability of tagged fish occurring in June. This dilution could be due to several factors including continued migration of the tagged groups out of the study area, immigration of fish from other areas where sampling did not occur, growth recruitment of fish to the gear that were too small to tag, and tagging

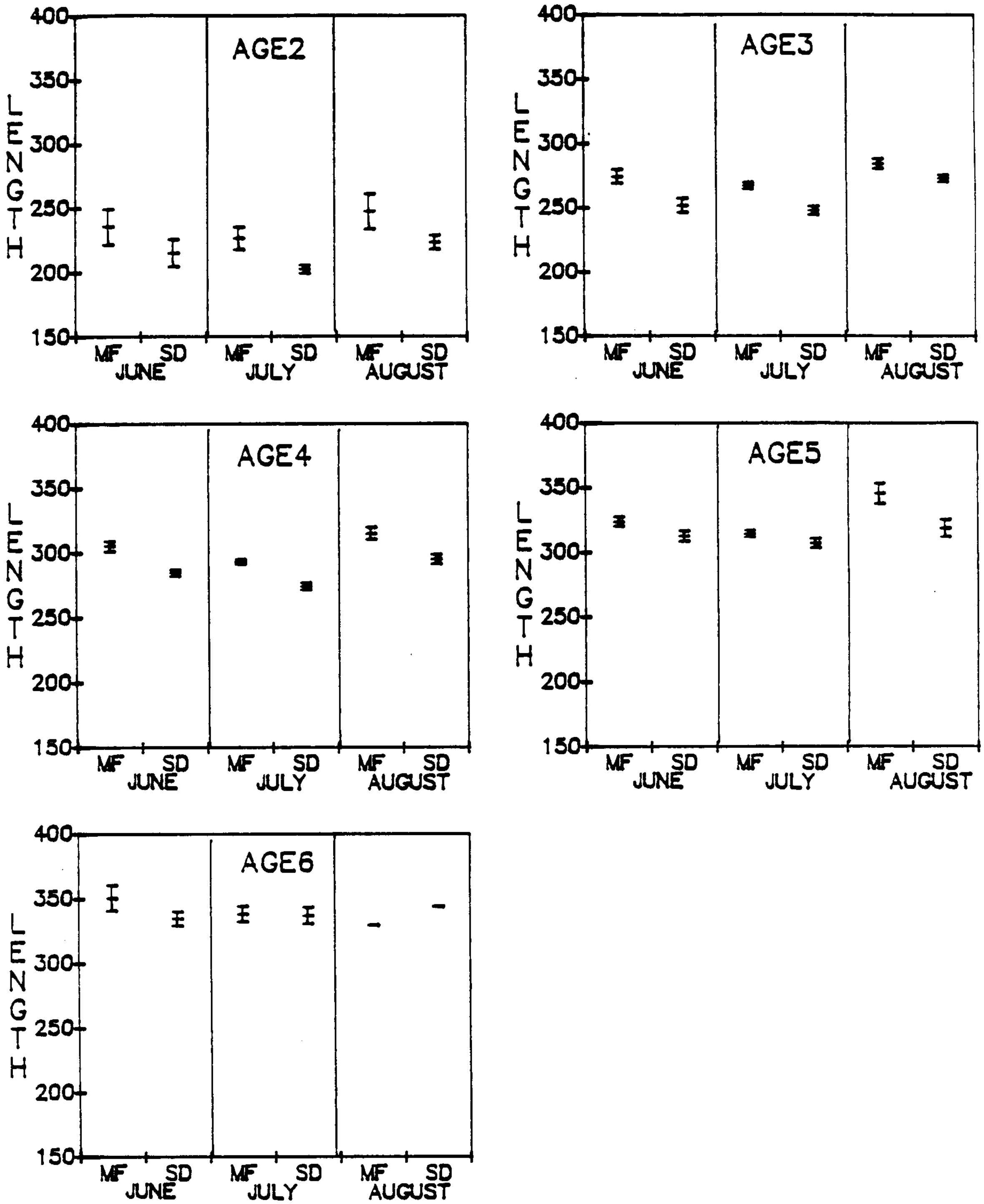

Figure 10. Mean length by age class with 95% confidence intervals for Gulkana River Arctic grayling sampled with electrofishing gear in the Middle Fork and Sourdough reaches of the Gulkana River from June through August, 1987.

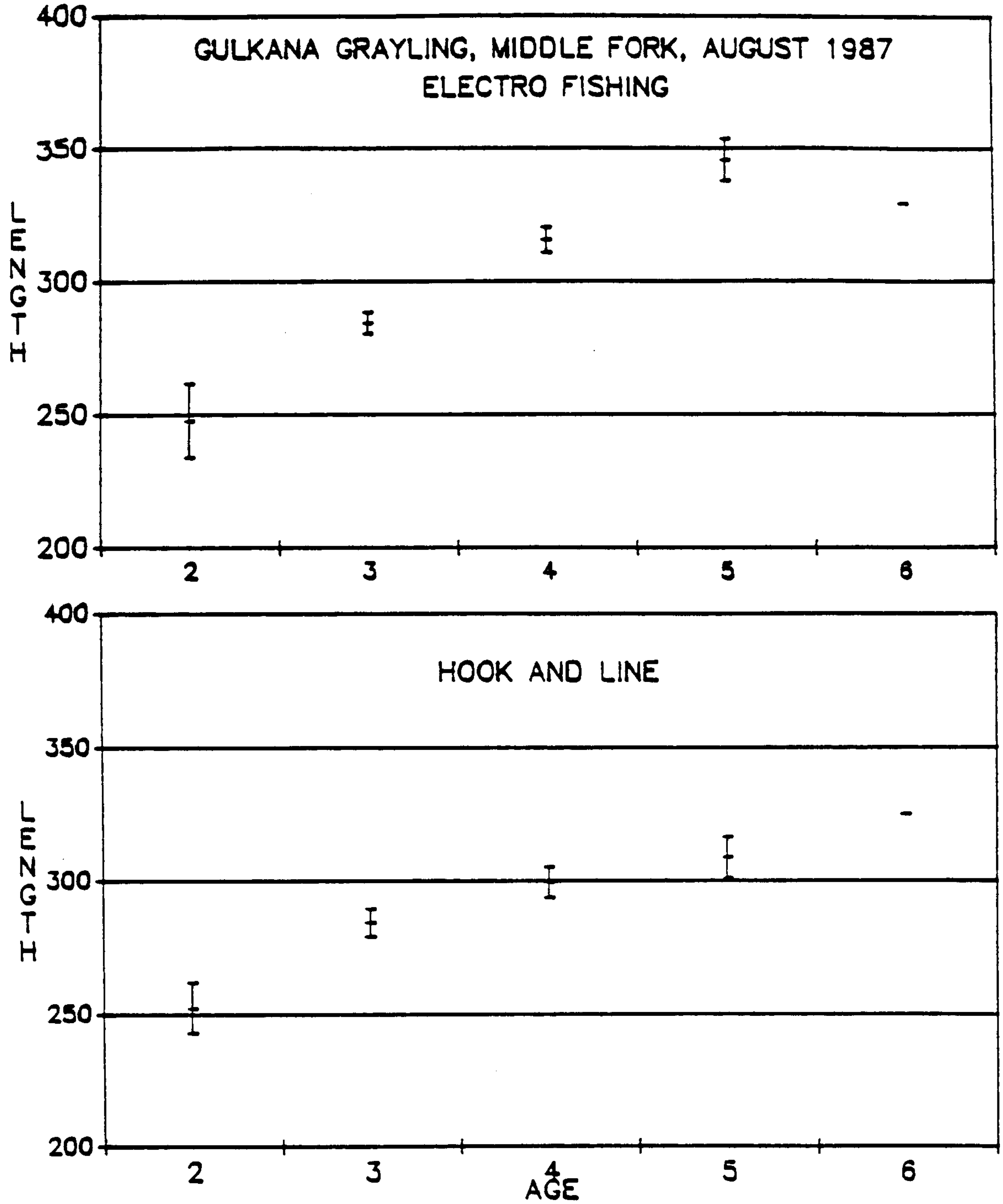

Figure 11. Mean length-at-age with 95% confidence intervals for electrofishing and hook and line gear in the Middle Fork reach of the Gulkana River during August, 1987.

mortality occurring over the summer. In all likelihood, these factors are acting in combination.

The question remains as to the geographic boundaries of the population being estimated. If Arctic grayling distribute evenly throughout the drainage after exiting their spawning streams, a population estimate based on weir tagging would be a drainage-wide abundance. If there is uneven distribution, then the estimate from weir releases cannot be geographically bounded nor will it be an unbiased estimate. Other reaches of the Gulkana River need to be sampled in July and August, including the tributaries, to determine if these migration patterns hold true in areas other than the Sourdough and Middle Fork reaches. The stratified Petersen estimator which allows for migration between reaches can be used if migration is limited to within the study areas. This would provide an estimate of abundance for the Sourdough and Middle Fork reaches alone. Again, sampling needs to be conducted in July in the West Fork, the Middle Fork, and the reach downstream from Sourdough to tag fish and look for recoveries to determine the extent of movements between these areas and the present survey reaches. These patterns of movement and stasis demonstrated for the fish tagged at the Sourdough Creek weir will need to be tested to determine if they hold true for Poplar Grove Creek because a weir, at present, can not be consistently established in Sourdough Creek.

We recommend that mark-recapture studies be continued on the Gulkana River drainage, including the operation of weirs at Poplar Grove Creek, and if possible at Sourdough Creek, to estimate the size of specific populations, relative fish sizes by age class, the extent of intrastream migrations of Arctic grayling in this system, the occurrence of stream-specific spawning populations, and whether grayling in these systems spawn annually. Surveys and tagging efforts should be expanded to other areas of the Gulkana River drainage to determine if discrete stocks are present and, through tag recoveries, determine if these areas contribute to the mainstem river sport fishery. These areas should include Paxson Lake and the reach of the Gulkana River upstream of the lake, the Middle Fork and West Fork and their major tributaries and associated lake systems, and the reach of river downstream from Sourdough. Efforts should also be made to document other spawning tributaries and the extent of mainstem river spawning. A sampling design which further delineates the Gulkana River into more definitive sublocations will allow the collection of more specific information on intrastream migration patterns.

Future studies should also include a comparison of scales to otoliths to validate the present age information collected for Arctic grayling in the Gulkana River. In addition, it is recommended that future tagging efforts include an analysis of tag loss. Although tag loss was apparent with some recaptured fish, the extent of tag loss could not be determined due to the multiple marks put out in the Gulkana River during previous studies.

Recreational fishing effort and harvest are expected to increase in the Gulkana River, and changes in bag, size, or possession limits, or methods and means regulations may be necessary to maintain the high quality of fishing now present. These studies would allow the formulation of long-term management strategies for Arctic grayling in the Gulkana River. Beginning in 1989, the sport fishing regulations for the Gulkana River were changed to five fish daily or in possession, only one of which could be 14 inches (approximately 345 mm fork length) or greater in length. Future surveys should monitor changes in the percent composition of larger grayling in the Gulkana River as a result of this regulation change.

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APPENDIX A

Appendix A1. Summary of adult[a] Arctic grayling tagging and scale sampling conducted on the Gulkana River during 1986, 1987, and 1988.

Sampling Site	Sampling Dates	Capture Technique	Number Caught	Number Tagged	Number Measured	Number Aged	Number Died	Scale Sampling Dates
1986								
Poplar Grove Creek	5/14-5/17	Dipnet	828	828[b]	828	0	0	--------------
Poplar Grove Creek	5/18-5/20	Weir	2,194	2,194	2,191	363	0	5/18-5/19
Paxson to Sourdough	6/27-7/1	Hook&Line	550	538	550	386	12	6/27-7/1
Paxson to Sourdough	7/16-7/21	Hook&Line	417	417	415	302	0	7/17-7/21
Paxson to Sourdough	7/28, 7/30 8/9, 8/11	Hook&Line	94	94	94	58	0	7/28, 7/30 8/9, 8/11
Sourdough Reach	8/18-8/20	Electro	830	819	818	3	6	8/18-8/19
1987								
Sourdough Creek	5/10-5/17	Weir	1,512	1,508	1,504	497	0	5/10-5/14
Poplar Grove Mouth	6/12-6/13	Electro	155	150	155	62	5	6/12
Paxson Lake Outlet	6/20	Electro	33	33	33	26	0	6/20
Sourdough Reach	6/22-6/25	Electro	966	948	965	146	17	6/22
Middle Fork Reach	6/27-6/29	Electro	360	355	358	164	5	6/27-6/28
Paxson Lake Outlet	7/14-7/15, 7/24	Electro	53	52	53	52	1	7/14-7/15, 7/24
Middle Fork Reach	7/16-7/19	Hook&Line	353	352	353	0	1	--------------
Middle Fork Reach	7/16-7/24	Electro	1,382	1,375	1,377	434	7	7/16, 7/19-7/20
Sourdough Reach	7/25-7/29	Electro	292	291	292	214	1	7/25-7/28
Middle Fork Reach	8/21-8/24	Electro	189	186	189	72	3	8/22, 8/24
Middle Fork Reach	8/25-8/26	Hook&Line	215	215	213	79	0	8/25-8/26
Sourdough Reach	8/10, 8/28-9/3	Electro	992	989	983	184	4	8/28-8/29, 8/31
Sourdough Reach	9/15-9/19	Electro	1,379	1,374	1,361	47	7	9/17
1988								
Sourdough Creek	5/5, 5/9	Hook&Line	78	78	78	75	0	5/5, 5/9
Poplar Grove Creek	5/10-5/22	Weir	4703	4703	4701	504	0	5/10-5/12
Sourdough Reach	6/23	Electro	9	9	9	0	0	--------------
Middle Fork Reach	6/23-6/28	Hook&Line	156	156	156	0	0	--------------
Middle Fork Reach	7/23-7/27	Both[c]	77	77	77	13	0	7/27
Sourdough Reach	8/5-8/6, 8/24-8/27	Electro	135	134	134	117	1	8/5-8/6, 8/24-8/27
Middle Fork Reach	8/26, 8/28	Both[c]	32	32	32	26	0	8/26, 8/28
Sourdough Reach	9/13-9/17	Electro	606	606	605	352	0	9/13-9/17
Middle Fork Reach	9/20	Electro	11	11	11	8	0	9/20
Gulkana Mouth	9/24-9/25	Both[c]	22	22	22	16	0	9/24

[a] All untagged grayling 200 mm FL or larger.

[b] Shrimp tags - no recovery possible.

[c] Electrofishing and Hook & Line.

Appendix A2. Summary of juvenile[a] Arctic grayling tagging and scale sampling conducted on the Gulkana River during 1986, 1987, and 1988.

Sampling Site	Sampling Dates	Capture Technique	Number Caught	Number Tagged	Number Measured	Number Aged	Number Died	Scale Sampling Dates
1986								
Poplar Grove Creek	5/14-5/17	Dipnet	22	22[b]	22	0	0	--------------
Poplar Grove Creek	5/18-5/20	Weir	51	51	51	1	0	5/18-5/19
Paxson to Sourdough	6/27-7/1	Hook&Line	5	5	5	5	0	6/27-7/1
Paxson to Sourdough	7/16-7/21	Hook&Line	1	1	1	1	0	7/17-7/21
Paxson to Sourdough	7/28, 7/30, 8/9, 8/11	Hook&Line	0	0	0	0	0	7/28, 7/30, 8/9, 8/11
Sourdough Reach	8/18-8/20	Electro	306	92	306	164	2	8/18-8/19
1987								
Sourdough Creek	5/10-5/17	Weir	1,417	73	1,417	106	0	5/10-5/14
Poplar Grove Mouth	6/12-6/13	Electro	46	2	46	18	0	6/12
Paxson Lake Outlet	6/20	Electro	0	0	0	0	0	6/20
Sourdough Reach	6/22-6/25	Electro	99	3	99	1	1	6/22
Middle Fork Reach	6/27-6/29	Electro	3	0	3	0	0	6/27-6/28
Paxson Lake Outlet	7/14-7/15, 7/24	Electro	1	1	1	1	0	7/14-7/15, 7/24
Middle Fork Reach	7/16-7/19	Hook&Line	30	0	30	0	0	--------------
Middle Fork Reach	7/16-7/24	Electro	19	1	19	1	0	7/16, 7/19-7/20
Sourdough Reach	7/25-7/29	Electro	50	1	50	18	1	7/25-7/28
Middle Fork Reach	8/21-8/24	Electro	7	0	7	0	0	8/22, 8/24
Middle Fork Reach	8/25-8/26	Hook&Line	0	0	0	0	0	8/25-8/26
Sourdough Reach	8/10, 8/28-9/3	Electro	102	0	101	39	1	8/28-8/29, 8/31
Sourdough Reach	9/15-9/19	Electro	14	0	14	0	0	9/17
1988								
Sourdough Creek	5/5, 5/9	Hook&Line	0	0	0	0	0	5/5, 5/9
Poplar Grove Creek	5/10-5/22	Weir	357	8	98	66	0	5/10-5/12
Sourdough Reach	6/23	Electro	0	0	0	0	0	--------------
Middle Fork Reach	6/23-6/28	Hook&Line	0	0	0	0	0	--------------
Middle Fork Reach	7/23-7/27	Both[c]	2	0	0	0	0	7/27
Sourdough Reach	8/5-8/6, 8/24-8/27	Electro	38	2	38	33	0	8/5-8/6, 8/24-8/27
Middle Fork Reach	8/26, 8/28	Both[c]	0	0	0	0	0	8/26, 8/28
Sourdough Reach	9/13-9/17	Electro	132	0	132	36	0	9/13-9/17
Middle Fork Reach	9/20	Electro	0	0	0	0	0	9/20
Gulkana Mouth	9/24-9/25	Both[c]	0	0	0	0	0	9/24

[a] All grayling less than 200 mm FL.

[b] Shrimp tags - no recovery possible.

[c] Electrofishing and Hook & Line.

Appendix A3. Summary of Arctic grayling recaptures[a] on the Gulkana River by study reach and sampling event during 1986, 1987, and 1988.

Sampling Site	Sampling Dates	Capture Technique	Total # Fish Caught	Recaptures[a] Number Caught	Number Measured	Number Died
1986						
Poplar Grove Creek	5/14-5/17	Dipnet	850	0	0	0
Poplar Grove Creek	5/18-5/20	Weir	2,249	0	0	0
Paxson to Sourdough	6/27-7/1	Hook&Line	558	3	2	0
Paxson to Sourdough	7/16-7/21	Hook&Line	423	5	0	0
Paxson to Sourdough	7/28, 7/30, 8/9, 8/11	Hook&Line	97	3	0	0
Sourdough Reach	8/18-8/20	Electro	1,136	10	10	0
1987						
Sourdough Creek	5/10-5/17	Weir	2,932	3	3	0
Poplar Grove Mouth	6/12-6/13	Electro	204	3	3	0
Paxson Lake Outlet	6/20	Electro	34	1	1	0
Sourdough Reach	6/22-6/25	Electro	1,103	38	31	2
Middle Fork Reach	6/27-6/29	Electro	370	7	6	0
Paxson Lake Outlet	7/14-7/15, 7/24	Electro	60	3	3	0
Middle Fork Reach	7/16-7/19	Hook&Line	394	11	2	0
Middle Fork Reach	7/16-7/24	Electro	1,471	71	70	3
Sourdough Reach	7/25-7/29	Electro	387	46	46	0
Middle Fork Reach	8/21-8/24	Electro	220	24	24	0
Middle Fork Reach	8/25-8/26	Hook&Line	229	13	12	0
Sourdough Reach	8/10, 8/28-9/3	Electro	1,142	48	47	0
Sourdough Reach	9/15-9/19	Electro	1,516	123	122	0
1988						
Sourdough Creek	5/5, 5/9	Hook&Line	81	3	3	0
Poplar Grove Creek	5/10-5/22	Weir	5,255	195	195	0
Sourdough Reach	6/23	Electro	11	2	2	0
Middle Fork Reach	6/23-6/28	Hook&Line	172	16	16	1
Middle Fork Reach	7/23-7/27	Both[b]	84	5	4	1
Sourdough Reach	8/5-8/6, 8/24-8/27	Electro	184	11	11	1
Middle Fork Reach	8/26, 8/28	Both[b]	34	2	2	0
Sourdough Reach	9/13-9/17	Electro	787	49	49	0
Middle Fork Reach	9/20	Electro	13	2	2	0
Gulkana Mouth	9/24-9/25	Both[b]	22	0	0	0

[a] Does not include multiple recaptures during a single sampling event or tags recaptured during the sampling event they were initially released in.

[b] Electrofishing and Hook & Line.

Appendix A4. Summary of tag numbers deployed in the Gulkana River for marking Arctic grayling during 1986, 1987, and 1988.

Sampling Site	Sampling Dates	Capture Technique	Adults[a] Tagged	Juveniles[b] Tagged	Total Tagged	Tag Series Deployed
1986						
Poplar Grove Creek	5/14-5/17	Dipnet	828	22	850	1-850[c]
Poplar Grove Creek	5/18-5/20	Weir	2,194	51	2,245	1001-3000, 4001-4250
Paxson to Sourdough	6/27-7/1	Hook&Line	538	5	543	90070-90200, 90301-90400, 90500-90599, 90700-90713, 90800-90999
Paxson to Sourdough	7/16-7/21	Hook&Line	417	1	418	4300-4344, 90201-90299, 90400-90499, 90600-90699, 90714-90799
Paxson to Sourdough	7/28, 7/30, 8/9, 8/11	Hook&Line	94	0	94	4801-4898
Sourdough Reach	8/18-8/20	Electro	819	92	911	4251-4300, 4351-4700, 20292-20820
1987						
Sourdough Creek	5/10-5/17	Weir	1,508	73	1,581	30001-31000, 36001-36588
Poplar Grove Mouth	6/12-6/13	Electro	150	2	152	31001-31154
Paxson Lake Outlet	6/20	Electro	33	0	33	31155-31187
Sourdough Reach	6/22-6/25	Electro	948	3	951	31188-31925, 31951-32165
Middle Fork Reach	6/27-6/29	Electro	355	0	355	32166-32520
Paxson Lake Outlet	7/14-7/15, 7/24	Electro	52	1	53	32521-32546, 32576-32598, 34991-34994
Middle Fork Reach	7/16-7/19	Hook&Line	352	0	352	32549-32575, 33001-33300, 33326-33350
Middle Fork Reach	7/16-7/24	Electro	1,375	1	1,376	32602-33000, 34001-34990'
Sourdough Reach	7/25-7/29	Electro	291	1	292	33301-33325, 33351-33631
Middle Fork Reach	8/21-8/24	Electro	186	0	186	33632-33822
Middle Fork Reach	8/25-8/26	Hook&Line	215	0	215	33823-34000, 35001-35040
Sourdough Reach	8/10, 8/28-9/3	Electro	989	0	989	35050-35075, 35092-36000, 37001-37052
Sourdough Reach	9/15-9/19	Electro	1,374	0	1,374	37054-38439

-Continued-

Appendix A4. (Page 2 of 2).

Sampling Site	Sampling Dates	Capture Technique	Adults[a] Tagged	Juveniles[b] Tagged	Total Tagged	Tag Series Deployed
<u>1988</u>						
Sourdough Creek	5/5, 5/9	Hook&Line	78	0	78	38501-38578
Poplar Grove Creek	5/10-5/22	Weir	4,703	8	4,711	105789-108000, 108501-111000
Sourdough Reach	6/23	Electro	9	0	9	105501-105509
Middle Fork Reach	6/23-6/28	Hook&Line	156	0	156	38800-38801, 105510-105664
Middle Fork Reach	7/23-7/27	Both[d]	77	0	77	38581, 105670-105740
Sourdough Reach	8/5-8/6, 8/24-8/27	Electro	134	2	136	105001-105048, 105741-105788, 105601-105100
Middle Fork Reach	8/26, 8/28	Both[d]	32	0	32	105049-105060, 105101-105120
Sourdough Reach	9/13-9/17	Electro	606	0	606	105121-105450, 111001-111276
Middle Fork Reach	9/20	Electro	11	0	11	105451-105461
Gulkana Mouth	9/24-9/25	Both[d]	22	0	22	105462-105483

[a] All grayling 200 mm FL or larger.

[b] All grayling less than 200 mm FL.

[c] Shrimp tags - no recovery possible.

[d] Electrofishing and Hook & Line.