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Bill Sheffield, Governor

Annual Performance Report for

POPULATION STRUCTURE AND DYNAMICS OF THE ARCTIC GRAYLING WITH EMPHASIS ON HEAVILY FISHED STOCKED

by

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RESEARCH PROJECT SEGMENT

State: Alaska

Name: Sport Fish Investigations of Alaska

Project: F-9-17

Study: R-I

Study Title: DISTRIBUTION, ABUNDANCE, AND NATURAL HISTORY OF THE ARCTIC GRAYLING IN THE TANANA DRAINAGE

Job: R-I-A

Job Title: Population Structure and Dynamics of the Arctic Grayling With Emphasis on Heavily Fished Stocks

Cooperator: Rolland Holmes

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ABSTRACT

Population estimates of Arctic grayling, *Thymallus arcticus* (Pallas), greater than 150 millimeters fork length, were conducted on five sections of the lower 90 miles of the Chena River. Populations on the three lower river Sections (2b, 8a, and Dam Site) were similar to past years. Population estimates in Section 10b were lower than past estimates, while estimates in Section 12 were much higher than those of previous years.

The Age-IV year-class was quite strong, and the Age-II, Age-III, and Age-V year-classes were weaker than normal. Correlation between year-class strength and average river discharge in the natal year was significant ($P < 0.95$) and indicated that high water inhibits either spawning success or egg or fry survival.

Average annual survival for grayling Ages IV-VIII was 0.48. Fishing mortality was approximately 20%.

Three measures of stock recruitment were evaluated. Catch-per-unit-effort of Age-I and Age-II grayling and standardized seining of young-of-the-year grayling appeared to be relatively accurate as recruitment indices. Population estimates of grayling 100-149 millimeters in fork length were not successful because recapture rates were low.

Creel-census information collected from May 1 to September 15, 1984 along the upper Chena River revealed that an estimated 17,090 angler hours were expended to harvest 9,623 grayling. The estimated catch rate of 0.59 grayling per hour was similar to previous catch rates. Angler pressure and harvest figures, by month, are presented, along with catch composition. Creel censuses since 1970 are summarized. Badger Slough spring-harvest studies provided an estimated catch rate of 1.0 grayling per hour. About 37% of these fish were of spawning size. In an average year, this would represent a harvest of about 1,700 spawners.

About 1,500 pond-reared grayling were stocked into the upper Chena River. Mean survival from sac fry to stocking of pond-reared fish was about 5%, and the mean fork length was 134 millimeters. A total of 92,000 hatchery-reared fingerlings were stocked in the Chena River, as well. These fish averaged 60.4 millimeters in length, which is similar to the mean size of wild young-of-the-year grayling.

Discriminant function analysis (LDF) of scale-pattern variables of young-of-the-year grayling from four separate groups (Chena River, Badger Slough, pond-reared, and hatchery grayling) was performed. If variables not related to length were used (for example, circuli spacings), LDF analysis was not successful in separating these groups. Length-related scale variables (for example, circuli counts) improved the accuracy of LDF classifications.

The grayling intrastream-migrations study was continued in 1984. A total of 42 grayling were recaptured. The use of surgically implanted radio transmitters for movement studies was evaluated. Transmitters lasted about 4 months, and tagged fish appeared to engage in normal movements. These studies will be continued to evaluate overwintering and spawning movements.

KEY WORDS

Arctic grayling, Tanana drainage, electrofishing, population estimates, creel census, migrations, stock structure, population dynamics, tagging, stream surveys and enhancement.

BACKGROUND

The Chena River is typical of the clear, runoff-type streams common in interior Alaska. The Chena River originates in the Tanana Hills about 100 mi east of Fairbanks at lat. 65° N, long. 145° W and flows westerly, emptying into the Tanana River just below the city of Fairbanks. The entire watershed occupies about 1,900 sq mi; the river basin is 100 mi long and a maximum of 40 mi wide. The river has been divided into 17 sections for study (Fig. 1) (Table 1).

The annual mean flow of the Chena River at Fairbanks is 1,418 ft^3/s, based on data collected by the U.S. Geological Survey since 1947. The maximum annual meanflow was 3,160 ft^3/s in 1949, and the minimum was 708 ft^3/s in 1958. The 1967 flood accounted for the record maximum flow of 74,000 ft^3/s through Fairbanks.

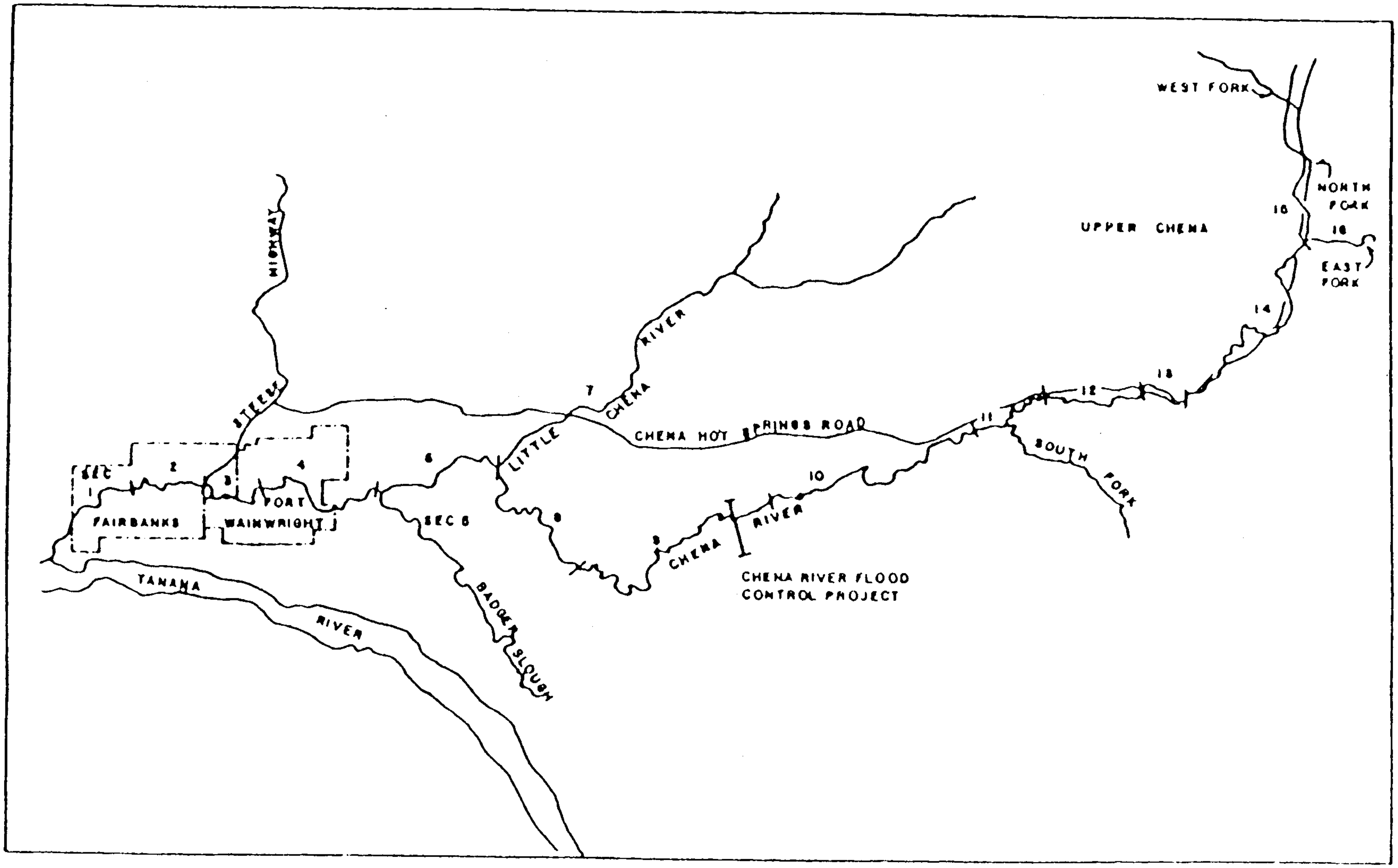

Figure 1. Chena River Study Sections.

Table 1. Chena River study sections.

Section number	Section name	River miles	Section Length (miles)
1	River Mouth to University Ave.	0-6	6.0
2a	University Ave. to Peger Road	6-8	2.0
2b	Peger Road to Wendell Street	8-11	3.0
3	Wendell St. to Wainwright Railroad	11-14.5	3.5
4	Wainwright Railroad Bridge to Badger Slough.	14.5-21.5	7.0
5	Badger Slough		16.5
6	Badger Slough to Little Chena	21.5-24.5	3.0
7	Little Chena River		61.5
8	Little Chena to Nordale Slough	24.5-31	6.5
9a	Nordale Slough to Bluffs	31-55.5	24.5
9b	Bluffs to Bailey Bridge	55.5-60	4.5
10	Bailey Bridge to Hodgins Slough	60-76	16.0
11	Hodgins Slough to Fourmile Creek	76-84	8.0
12	Fourmile Creek to First Bridge	84-88.5	4.5
13	First Bridge to Second Bridge	88.5-91	2.5
14	Second Bridge to North Fork	91-95.5	4.5
15	North Fork of Chena River		35.0
16	East Fork of Chena River		62.0
17	West Fork of Chena River		35.0

Like most clear, runoff-type streams in interior Alaska, the Chena River supports a large population of Arctic grayling, *Thymallus arcticus* (Pallas). Although the Chena River contains many species of fish, the Arctic grayling is the principal species of recreational importance. Because of its proximity to Fairbanks, the Chena River supports the largest grayling fishery in the state.

The Chena Hot Springs Road, which parallels the Chena River from Mile 26 to its terminus at Mile 60, crosses the river seven times, providing easy access for fishermen and recreationists alike. It is in this area of intense fishing pressure that the 1984 Creel Census was conducted. Also within this area is the 250,000-acre Chena River Recreation Area. Recent campground construction here by the Alaska Department of Natural Resources, Division of Parks, has increased access to the river and furthered recreational use.

The Department of Fish and Game has monitored angler use and harvest levels on the upper Chena since 1967 (Van Hulle, 1968; Roguski and Winslow, 1969; Roguski and Tack, 1970; Tack, 1971, 1973, 1975, 1976; Hallberg, 1977-1982; Holmes, 1983, 1984). Use levels have shown a general increase, while catch rates and fish size have remained relatively constant.

Intensive studies of Arctic grayling stocks have been conducted in selected index areas for several years. Standard mark and recapture methods to estimate graying numbers were initiated by Roguski and Winslow (1969), and continued by Roguski and Tack (1970), Tack (1971-1976), Hallberg (1977-1982) and Holmes (1983, 1984). Information obtained during the population estimates also includes length frequencies, age and length composition, and annual survival/mortality--all of which aid in understanding grayling life history and evaluating the health of the exploited stocks of the Chena River.

The U.S. Army Corps of Engineers has constructed a flood-control project on the Chena River at River Mile 47. The project is designed to channel flood waters from the upper Chena River directly into the Tanana River, bypassing the city of Fairbanks and the lower Chena River, thus protecting both from flood waters. Other factors affecting the river include a hot springs and resort on the North Fork, numerous recreation cabins on the North and West Forks, and a military campground near Mullen Slough. Hydraulic gold-mining operations are active on the Little Chena River and East Fork, and mining activities are scheduled on the South and West Forks. These activities, along with the problems associated with a city and military complex located in the lower 15 mi of the river, pose a variety of management problems for the Sport Fish Division in our on-going efforts to maintain the integrity of the Chena River and its fauna.

RECOMMENDATIONS

Research

1. Population estimates on the five index sections of the Chena River

should be continued. Sampling effort should be increased on Sections 8a, Dam Site, 10b and 12 to increase the precision of the estimates and to allow for cohort population estimates.

2. The five index estimates should be used as the basis for a total Chena River population estimate.

3, Index-area population estimates and age and length sampling should be performed on the Salcha and Chatanika Rivers.

4. Age-structure sampling should be increased from all index sampling areas to improve precision of cohort analysis. Yearly cohort population changes should be estimated.

5. Recruitment indices should be continued, and sampling effort increased. Population estimates of grayling 100-149 mm fork length should be discontinued as a recruitment index.

6. The relationship between year-class strength and average discharge should continue to be investigated.

7. Investigations of grayling populations should continue on headwaters of the major river systems of interior Alaska.

8. Knowledge of mortality factors of Chena River grayling should be refined and emphasis be placed on estimates of fishing mortality.

9. Creel-census efforts on the upper Chena River should be continued, and sampling effort increased. Single angler interviews should be obtained and catch sampling increased.

10. Angler interviews during spring fisheries on Badger Slough and other area streams should be performed to estimate catch-per-unit-effort (CPUE), obtain catch samples, and determine the effect of fisheries on spawning stocks.

11. Use of radio-telemetry to investigate spawning, stock mixing and overwintering habitat should be evaluated.

12. Increased stocking levels in rearing ponds should be evaluated. Improved techniques for trapping and removing pond-reared fish should be developed.

13. All fish stocked in the open-river system should be micro-wire tagged.

14. The contribution of enhancement fish to the population structure and the fishery should be evaluated.

15. A model of predicted grayling yield based on mortality, recruitment, movement, effort and habitat data obtained from the Chena River should be developed.

Management

1. Monitoring of development projects affecting the Chena River should be continued.

2. Recruitment indices should be monitored to determine the need for stock enhancement of the Chena River.

3. Grayling egg sources should be assessed, and production of fry in rearing ponds should be evaluated.

OBJECTIVES

1. To estimate the number of grayling, as well as assess and compare age and size composition of the grayling stocks in five Chena River and one Chatanika River index sections during July and early August.

2. To determine catch-per-unit-effort and age and size composition of grayling harvested in major Fairbanks area fisheries, including the Chena and Chatanika Rivers and Badger and Piledriver Sloughs. To also perform a statistically based creel census to estimate angler hours and harvest on the upper Chena River from May 1 to September 15.

3. To evaluate the importance of yearly movements and migrations of grayling within the Chena River in contributing to angler harvest and stock maintenance.

4. To estimate total annual mortality of grayling stocks within five Chena River and one Chatanika River index sections. To attempt to estimate fishing mortality in the upper Chena River index section.

5. To evaluate three methods of indexing or estimating stock recruitment in the five Chena River and one Chatanika River index sections.

6. To evaluate growth and survival of grayling stocked into four summer rearing ponds to determine their suitability for future stock enhancement of the upper Chena River.

7. To perform surveys of the grayling population

structure of interior Alaska headwater streams, as time permits.

8. To develop a model of predicted grayling yield based on growth, mortality, recruitment, movement and harvest data obtained from the Chena River.

TECHNIQUES USED

Intensive studies of Arctic grayling in 1984 were conduced on five 3-mi index sections (2b, 8a, Dam Site, 10b and 12) representing various habitat types on the Chena River.

Sections 2b and 8a lie below the newly constructed Chena River Lakes Flood Control Project and may be directly affected during times of flooding. Section 2b lies adjacent to Fairbanks, is easily accessible and over the years, has been exposed to heavy development. Section 8a is located about 15 mi upstream of Fairbanks. Although Section 8a remains fairly accessible, it has not yet experienced intensive development. The upper three sections are located above the flood-control structure. The area known as the Dam Site is the 3-mi stretch of river directly upstream of the control structure. In this area, flood waters from the Chena River enter the floodway and eventually find their way into the Tanana River. Estimates here began in 1972 (Tack, 1973) and will be continued to monitor any changes in the grayling population structure related to the flood-control project. Section 10b is undeveloped and relatively inaccessible, and angler use is minimal; thus, it serves as a control area in our population estimates. A new index area, Section 12, was initiated in 1983. This section is located in the upper Chena River in the heavily fished portion of the river. Population size, and age and growth information from this section will be compared with catch-sample data obtained from the upper Chena River creel census. Additional intensive sampling was performed on a 1.5-mi section of the Chatanika River.

Grayling for population estimates, and age and length composition were captured by a boat-mounted electrofishing unit described by Van Hulle (1968) and Roguski and Winslow (1969). Electrofishing passes were made through each of the 3-mi-long Chena River index sections on three successive days. Mark-recapture population estimates and their associated 95% confidence intervals were calculated using the Schnabel technique (Ricker, 1978).

Scale samples for age determination were taken from a subsample of 25% of the fish captured during the electrofishing runs. Scales were cleaned and impressed on 20-mm-thick acetate using a Carver press at 20,000 lb/in^2 heated to 200°F for 30 seconds. Scales were aged using a Bruning 200 microfiche reader.

Age frequencies obtained from the index sampling in Sections 2b, 8a, Dam Site and 10b through 1983 were multiplied by population estimates to obtain per-mile estimates of numbers of grayling in each age group.

These data were used to estimate annual survival and mortality by two different methods: catch-curve analysis and cohort analysis. The rate of fishing mortality was estimated by calculating the percent of the total Chena River mortality attributable to fishing (obtained by creel census).

Three methods of indexing stock recruitment were evaluated in 1984. The first method involved Schnabel mark-recapture population estimates of 100-149 mm fork length (FL) grayling in each index section. These population estimates were made concurrently with the estimates of grayling greater than 150 mm FL. By the second method, Age-I and Age-II grayling were segregated using length-frequency analysis. The CPUE of each of the age-classes in each index section was then considered as an index of abundance. For the third method, a series of seine hauls was made in the upper, middle, and lower Chena River. The CPUE for young-of-the-year grayling from these seine hauls was used as an index of the relative abundance of Age-0 grayling. The accuracy of the Age-I and Age-II CPUE estimates was tested using regression analysis (Zar, 1974).

A roving creel-census was conducted along the upper Chena River. Total angler hours were estimated using counts of fishermen at 2 p.m. on six randomly selected days per month within weekend and weekday strata (Holmes, 1981). Angler interviews were conducted during the roving creel-census to compute catch statistics and gather angler-profile information. All angler-caught fish were measured, and scale samples taken. Angler interviews were conducted in spring on the Badger Slough grayling fishery to index catch rates and determine the proportion of spawning adults in the catch.

Two techniques were used to stock grayling in the Chena River for the first time in 1984. The first technique involved stocking grayling fry in small winter-kill ponds in the spring for rearing, then removing them and stocking them in the Chena River in the fall. The second method involved stocking hatchery-reared grayling fingerlings directly in the Chena River in late August.

Discriminant function scale analysis was performed in 1984 in an effort to separate enhancement fish from wild Chena River grayling. A sample of about 100 scales was obtained from the two groups of enhancement fish (hatchery and pond-reared) before they were stocked in late August and early September. In late August wild young-of-the-year grayling in the main Chena River (across from Ft. Wainwright) and in Badger Slough (just below Nordale Road) were sampled with a 30-ft beach seine. Badger Slough fish were included as a group because a previous study (Walker, 1983) indicated that this tributary possibly provided a significant proportion of the recruitment to the Chena system.

Scales were removed from the area above the lateral line below the posterior insertion of the dorsal fin. Fork lengths of all sampled fish were recorded.

Scales were mounted between two microscope slides and projected at 100X magnification on a microcomputer digitizing system at the Commercial Fisheries Division Stock Biology Laboratory in Anchorage, as described by Conrad (1984). A hand-operated cursor was used to enter the location of scale focus and each subsequent circulus to the nearest 0.01 in. These scale measurements were made at a 45° angle, ventral from the anterio-posterior scale axis.

These data, along with length and sample-location data for each fish, were recorded on a flexible magnetic disk.

The method used to discriminate Arctic grayling by these scale measurements was Fisher's LDF. If equal, multivariate, normal distributions are assured, LDF classification scores are converted to posterior probabilities of group membership (Dixon and Brown, 1981). Each case was assigned to the group for which it had the highest possibility of membership.

The LDF selects classification variables in a stepwise manner based on F-statistics. A large F-statistic indicates a large difference between groups. Additional variables are added to the discriminant function if the new equation is significantly different ($\alpha = 0.05$) from the reduced model. All discriminant analyses were performed with the BMDP 81 (Dixon and Brown, 1981) statistical package available on the University of Alaska computer system.

To maximize the number of variables available for analysis, all scale samples with fewer than four circuli were excluded. This resulted in a loss of 17 fish from the hatchery sample. This also allowed comparison with another grayling scale-pattern study (Walker, 1983) in which only the first four circuli were analyzed. The use of circuli counts alone as a stock separation tool was also evaluated.

Grayling-movement studies emphasized the evaluation of surgically implanted radio transmitters. Four Advanced Telemetry Systems BEI 10-35 transmitters (weight, 13 g; tag life, 7 months) and four ATS RM 625 transmitters (weight, 9.5 g; tag life, 4 months) were implanted in Chena River grayling. The transmitters were surgically implanted in the body cavity above the pelvic girdle with the antenna trailing behind the fish (Ross, 1981). Tag frequencies ranged from 150.000 to 151.000 MHz. After the surgery the grayling were held overnight before release. Transmitter signals were monitored with a Telonics TS-1 Scanner/ Processor, a Telonics TR-2 Biomedical Telemetry Receiver, and a Telonics RA-2AK antenna mounted on the wing strut of a Cessna 185 aircraft.

FINDINGS

Population Estimates

Chena River:

All estimates of the number of grayling per mile for Sections 2b, 8a, and the Dam Site were similar to estimates obtained in 1983 (Table 2).

Table 2. Population estimates for Arctic grayling greater than 150 mm fork length in index sections of Chena River, 1968-1984.

River Section	Year	Date	Grayling per mile (Schnabel estimate)
2b	1968	...	767
	1969	...	1,323
	1970	July 2-10	1,479
	1971	Aug. 30-Sept. 3	2,095
	1972	June 22-26	978
	1973	July 3-10	679
	1974	July 25-28	642
	1976	July 22-24	596
	1977	July 11-14	479
	1978	July 25-28	254
	1979	July 26-30	316
	1980	July 1-4	463
	1981	Aug. 7-10	419
	1982	July 16-20	185
	1983	July 13-15	346
	1984	July 16-18	338
8a	1979	Aug. 20-23	269
	1980	July 14-17	284
	1981	Aug. 3-6	359
	1982	July 13-15	139
	1983	July 5-7	190
	1984	July 3-6	223
Dam Site	1972	June 27-29	1,306
	1973	July 18-19	800
	1974	July 9-11	416
	1976	Aug. 4-6	464
	1977	July 26-30	437
	1978	Aug. 8-11	495
	1979	July 17-20	261
	1980	July 29-Aug. 1	339
	1981	Aug. 11-14	483
	1982	July 13-15	371
	1983	July 8-12	334
	1984	July 9-11	287

Table 2. (Cont.) Population estimates for Arctic grayling greater than 150 mm fork length in index sections of Chena River, 1968-1984.

River Section	Year	Date	Grayling per mile (Schnabel Estimate)
10b	1970	June 7-July 7	1,873*
	1980	Aug. 12-15	1,163
	1981	July 21-24	1,391
	1982	July 28-30	1,400
	1983	July 19-21	1,458
	1984	July 19-20	788**
12	1983	July 19-21	362
	1984	July 31-Aug. 3	2,109

* Estimated for the entire 16 mi of Section 10.

** Petersen estimate.

However, the estimated population of Section 10b was slightly more than half of the 1983 estimated population, while the estimate for Section 12 was more than five times greater than the 1983 estimate.

The population estimate for Section 2b, (338 grayling per mile) approximates the 5-year average for this Section (346 grayling per mile). The slight increase in the estimate for Section 8a brings the estimated population size to near the 5-year average of 248 grayling per mile, and the estimated populations for the Dam Site is down slightly from the 5-year average of 358 grayling per mile. Recapture rates on all these sections were relatively high and the resultant 95% confidence intervals were fairly narrow (Table 3).

In sections 10b and 12, however, high water hampered field work, and recapture rates were so low that estimates were virtually useless. It appears that additional sampling days will be required to reduce the confidence intervals for these two sections.

Chatanika River:

The estimate of 388 grayling per mile in the Chatanika River index section is about 110 grayling per mile greater than the 1982 estimate and almost the same as the 1972 estimate (Tack 1973). The recapture rate was relatively high, and the confidence interval relatively small.

Index-Sampling Catch Rates

Chena River:

As in the previous 2 years, catch rates during index sampling were not a good indication of population size. For example, in Section 10b, the population estimate was 1,400 grayling per mile in 1982, with a catch rate of only 150 grayling per days, while in 1984 the estimated population was nearly half that in 1982, even though the catch rate was greater (Table 3).

It appears, then, that catchability, which can be affected by numerous factors other than population size, is too variable to make catch rate a reliable indicator of population size.

Chatanika River:

The catch rate of 83 grayling per day in 1984 is lower than the catch rate of 118 grayling per day in 1982, while the per-mile population estimate was more than 100 grayling per mile greater in 1984 than in 1982. Again, this indicates that catch rates are probably not reliable as indicators of population size.

Age and Length Structure

Chena River:

Age determinations were made from scales sampled from 436 grayling

Table 3. Population estimates and 95% confidence intervals, number of tagged fish recaptured, catch rates, and catchability estimates of Arctic grayling greater than 150 mm fork length, as well as water clarity, for five sections in the Chena River and one in the Chatanika River, 1984.

Section (River Mile)	Date of Estimate	Number Recaptured	Catch Rate (Fish/Day)	Water* Clarity (in)	Catchability (% Caught/Day)	Schnabel Estimate	
						Fish/mi	95% C.I.Fish/mi
2b (8-11)	July 16-18	68	180	32.7	17.8	338	267-429
8a (26-29)	July 3,5,6	25	87	40.7	13.0	223	152-344
Dam Site (46-49)	July 9-11	27	97	50.3	11.3	287	198-436
10b (66-69)	July 19-20	11	171	79	7.2	788**	440-1,605
12 (85-88)	July 31 Aug. 2-3	3	84	86	1.3	2,109	719-10,547
Chatanika	Aug. 15-18	32	83	26.7	14.3	388	276-564

* Water clarity measured with a standard 10-in Secchi disk.
** Petersen Estimate.

captured during the index sampling (Table 4). As predicted, the Age-IV year-class was quite strong (41.1% of the total population). This is well above the previous 10-year average of 21.4%. On the other hand, the normally strong Age-III year-class was quite weak (12.4% of the total population)--well below the 10-year average of 30.2%. These two year-classes normally make up the bulk of the catchable-size fish in the population and are thus important in monitoring the fishery.

The Age-II year-class (7.3% of the population) is also well below the 10-year average of 21.7%. This suggests that in 1985 both the Age-III and Age-IV classes will be quite weak. A combination of weak Age-III and Age-IV classes could result in low population estimates and reduced angler catch rates.

Poor spawning success or poor young-of-the-year survival appear to be the major determinants of year-class strength. Once again, high negative correlations were found between numbers of grayling and the average rate of discharge during May, June and July of their natal years ($r = -0.94$; $p \leq 0.95$, and $r = 0.89$, $p \leq 0.95$ for Age-III and Age-IV grayling, respectively (Fig. 2). Significant correlations were also found between CPUE of Age-I and Age-II grayling and water flow in their natal years ($r = -0.99$ and -0.93 for Age-I and Age-II grayling, respectively) (Fig. 3).

The consistent nature of these correlations for several age-classes over 5 years indicates that high water has a very drastic effect on survival of weak-swimming young-of-the-year grayling. Knowledge of water flows may be combined with young-of-the-year estimates, in the future, to refine recruitment estimates and help establish stocking levels. In a similar study, Crecco and Savoy (1984) found that mean water flow, water temperature, and total precipitation were all significantly correlated with the year-class strength of American shad (*Alosa sapdissima*). On the other hand, they found no correlation between spawning-stock size and year-class strength.

All 2,099 grayling captured during the index-area sampling were measured for length-frequency analyses (Table 5). Length ranges are similar to those obtained in the past. However, the modal length ranges have shifted slightly upwards and represent the shift of the major year-class from Age-III to Age-IV.

As in the past, the mean lengths and percentage of mature grayling (greater than 270 mm) tend to increase between Sections in an upstream direction. Section 2b and 8a average only 0.4% mature fish. The Dam Site and Sections 10b and 12 had 8.5%, 4.5% and 10.1% mature fish, respectively. These values all are less than those in 1983, as are the average lengths in all Sections except Sections 2b and 12 (Table 6). The continuing decline in the numbers of older and larger fish is probably caused by angler harvest.

The mean length of young-of-the-year grayling sampled during recruit index seining was 51.0 mm, which is considerably less than the mean length of young-of-the-year grayling in 1983 (67.4 mm). This decreased

Table 4. Age and length composition of 436 randomly sampled Arctic grayling in Sections 2b, 8a, Dam Site, 10b and 12, Chena River, 1984.

Fork Length (mm)	Age I	II	III	IV	V	VI	VII	VIII	
50-59									
60-69									
70-79	4								
80-89	23								
90-99	24								
100-109	15								
110-119	12								
120-129	2								
130-139	1	4							
140-149	1	9							
150-159		8							
160-169		10	8	1					
170-179		-	18	7					
180-189		1	14	24					
190-199			11	39	1				
200-209			2	47	5				
210-219			1	28	8				
220-229				23	6				
230-239				6	9	4			
240-249				2	6	11			
250-259				2	-	7	1		
260-269					2	10	2		
270-279						4	1		
280-289						4	1		
290-299							2	2	
300-309								0	
310-319								1	
320-329								0	
330-339								1	
340-349								1	
350-359								0	
360-369								1	
400- +									
Percent of sample	18.8	7.3	12.4	41.1	8.3	9.2	1.6	1.4	Total
Number	82	32	54	179	36	40	7	6	436
Mean Length	97.0	152.6	181.8	213.2	225.6	257.0	274.7	321.4	...
Length Range	73-145	131-185	163-210	169-257	192-264	230-289	253-295	290-368	...

Table 5. Length frequency (in percent of sample) of 2,099 grayling sampled from five sections of the Chena River and one section of the Chatanika River, 1984.

Fork Length (mm)	River Section					
	2b	8a	Dam Site	10b	12	Chatanika River
60-69			0.7			
70-79		2.0	1.0	0.7	0.7	
80-89	2.2	10.0	8.8	2.8	0.7	1.4
90-99	1.8	11.1	8.1	7.8	1.5	10.7
100-109	3.1	10.0	3.3	6.6	2.2	9.7
110-119	6.9		0.7	1.7	0.7	2.1
120-129	2.8	0.3		0.5		0.3
130-139	5.9	0.3		0.5	3.0	1.0
140-149	3.7	1.4	0.3	1.7	3.3	0.7
150-159	5.7	2.0	0.7	1.2	1.9	1.7
160-169	7.8	2.7	2.0	1.7	3.0	3.5
170-179	5.1	7.1	8.5	3.5	5.2	6.2
180-189	9.0	13.8	11.1	7.3	7.4	8.3
190-199	9.2	13.5	13.0	15.0	7.0	12.8
200-209	10.6	6.4	12.1	15.1	16.3	10.7
210-219	10.8	7.4	4.6	11.0	10.4	3.8
220-229	10.8	5.7	5.2	3.8	7.4	6.9
230-239	5.3	4.0	4.2	4.0	4.1	5.5
240-249	2.9	5.4	3.6	3.5	6.3	6.6
250-259	1.4	2.4	1.3	4.9	3.0	4.1
260-269	0.2	1.7	2.6	2.6	5.2	1.0
270-279	0.2		1.6	0.9	2.6	1.7
280-289		0.3	2.3	1.4	1.9	
290-299		0.3	1.6	0.9	3.0	
300-309			1.3	0.2	0.4	0.7
310-319			1.0	0.2	0.7	0.3
320-329				0.5	1.1	
330-339			0.7		0.4	0.3
340-349				0.2	0.4	0.3
350-359				0.2		
360-369					0.4	
400- +						
Number	510	297	307	425	270	290
Mean length	182.4	172.9	185.4	189.3	208.3	182.8
Length range	81-270	72-291	66-337	75-352	76-368	86-334

Table 6. Mean fork lengths (mm) of Arctic grayling sampled from index-area population estimates, 1976-1984.

Year	Chena River Section				
	2b	8a	Dam Site	10b	12
1976	201		220		
1977	190		204		
1978	181		183		
1979	178	193	192		
1980	178	186	204	206	
1981	177	196	187	178	
1982	171	174	188	202	
1983	173	181	216	206	198
1984	182	173	185	189	208

growth rate is probably attributable to the very high, muddy water occurring in 1984. The correlation between young-of-the-year growth rate and turbidity is important in the placer-mining issue and will be examined in future years.

Chatanika River:

The general age structure of Chatanika River grayling is very similar to that of the Chena River (Table 7). As with the Chena River, the Age-IV class was dominant, and both the Age-II and Age-III year classes were quite weak. Yearly fluctuations in water-discharge rates are quite similar for these two rivers and probably account for the similarity in age-class structure between the two rivers.

Mean lengths of specific age groups are also similar between the Chena and Chatanika Rivers. The overall length structure of Chatanika grayling is most closely related to the Dam Site Section (Table 5). The proportion of spawning size adults (3.3%) in the Chatanika is slightly higher than in 1982 (2.3%).

Survival and Mortality

Chena River:

By following the declines in the number of individuals in a year-class from 1980-1984 (cohort analysis), estimates of survival and mortality were obtained. A catch-curve plot of log number of grayling at age indicated that Age-III grayling may not be fully recruited (Fig. 4). Therefore, mortality and survival estimates were made only for Age-IV and older fish. The slope of the least-square regression of catch curve for specific cohorts (natal years 1974-1979) provided relatively consistent estimates of total survival ranging from 0.40 to 0.58 (Table 8). Catch-curve estimates of survival using age-class structure within a specific year ranged from 0.28 to 0.59. The means of both estimating techniques were very similar: 0.48 and 0.47, respectively. The average annual survival of 0.48 and corresponding annual mortality of 0.52 will be used for further calculations. These values represent an increase in estimated survival over past years. This increase is attributable to the use of the least-squares estimating technique, rather than ratio methods, which were used in the past.

Chatanika River:

Because age-structure data for several consecutive years are not available on the Chatanika River, cohort-specific estimates of survival and mortality are not possible. A least-squares fit of the descending limb of the catch curve of age composition in one year produced a survival estimate for 1984 of 0.41. In 1982 the total annual survival estimate by this method was 0.45.

Table 7. Age and length composition of 73 randomly sampled Arctic grayling from the Chatanika River below the Elliot Highway Bridge, 1984.

Fork Length (mm)	Age I	II	III	IV	V	VI	VII	VIII
80-89	2							
90-99	3							
100-109	8							
110-119	3							
120-129								
130-139								
140-149		1						
150-159		2	1					
160-169			2					
170-179			4	1				
180-189			1	4				
190-199				8	2			
200-209				8	3			
210-219				...	1			
220-229				1	5			
230-239					1	1		
240-249					4	...		
250-259					1	3	1	
260-269						1		
270-279								
280-289								
290-299								
300-309								1
370-379								
Percent of sample	21.9	4.1	11.0	30.1	23.2	6.9	1.4	1.4
Number	16	3	8	22	17	5	1	1
Mean Length	100.8	149.3	172.0	196	224.6	251.4	258	301
Length Range	86-112	141-157	159-188	178-227	195-258	227-262		

Table 8. Estimated mean number of Arctic grayling per mile for each age group (IV-VIII), combined Chena River index Sections (2b, 8a, Dam Site, and 10b). Cohort and life-table estimates of instantaneous survival, total mortality and survival are presented.

Age	Year Sampled 1980	1981	1982	1983	1984	Natal Year	Cohort Analysis Survival (S)	Mortality (A)	Inst. Mortality (Z)
IV	194	65	204	47	29				
V	81	92	42	101	29				
VI	47	45	25	36	33	1979			
VII	9	12	16	15	7	1978	0.40	0.60	0.91
VIII	1	6	16	9	6	1977	0.51	0.49	0.68
						1976	0.42	0.58	0.88
						1975	0.47	0.53	0.76
						1974	0.58	0.42	0.54

Catch Curves

	1980	1981	1982	1983	1984
Survival (S)	0.28	0.51	0.55	0.59	0.45
Mortality (A)	0.72	0.49	0.45	0.41	0.55
Inst. Mort.(Z)	1.27	0.67	0.60	0.53	0.80

These values are somewhat lower than those obtained for the Chena River. Estimates obtained by this method are so variable, however, that they should be regarded only as general indices of survival. As more yearly age-structure information becomes available, these estimates of survival and mortality should be refined using cohort analysis.

Fishing Mortality

Chena River:

The proportion of the total mortality due to fishing was calculated for 1984 and recalculated for 1983 using consistent mortality, population information and harvest estimates (Table 9).

In 1984, there were an estimated 77,782 grayling in the lower 108 mi of the Chena River. With an annual mortality of 52%, an estimated 40,446 grayling died in the Chena River in 1984. From the creel census, an estimated harvest for the total river of 15,765 grayling was obtained. Thus, about 39% of the total mortality was caused by angler harvest. The estimated rate of fishing mortality (exploitation rate) for 1984 was 20.3%, and the estimated rate of natural mortality was 31.7%.

The 1983 estimate of fishing mortality was scaled downward considerably to 24.0%. This lower estimate resulted from higher total-river-population estimates and a lower total-mortality estimate. The 1983 and 1984 fishing-mortality estimates are relatively consistent and seem to indicate an average annual-exploitation rate of 20-25% on the Chena River. Because of the assumptions involved in these estimates they should be considered only as relative values.

Recruitment

Chena River

The Chena River fishery is heavily dependent upon the Age-III and Age-IV year-classes. Because low recruitment to either of these year-classes can have a major effect on population structure and the fishery, three methods of indexing recruitment were developed in 1983.

The first method, population estimates of 100-149 mm long fish, proved unreliable because recapture rates were very low. In 1984, only two fish were recaptured in the five index sections, and mark-recapture population estimates were impossible to make. With increased sampling effort in future years, these estimates may be feasible, but it appears that, with the present sampling effort, population estimates of 100-149 mm FL grayling should not be continued.

The second index of recruitment involved determining the index sampling CPUE of Age-I and Age-II grayling using length-frequency analysis. This analysis indicates a very strong Age-I class and a weak Age-II class (Table 10). A significant negative correlation ($r = -0.97$, $p < 0.05$) was found between the catch rate of Age-I fish and the catch rate of Age-II fish in the following year (Fig. 5a). The slope of the

Table 9. Estimated rates of total, natural and fishing mortality (rate of exploitation) for the entire Chena River, 1983 and 1984.

Year	Mean No. of Fish/mi	Total Population In Lower 108 Miles	Total Mortality (A)	Estimated No. of Fish Dying Each Year	Harvest Upper Chena	Harvest Lower Chena	Harvest Total	Percent Fishing Mortality	Fishing Mortality (U)	Natural Mortality (V)
1983	722*	77,976*	0.52	40,548	10,835	7,894	18,729	46.2	0.24	0.280
1984	720.2*	77,782*	0.52	40,548	9.623	6,142**	18,728*	39.0	0.203	0.327

* Estimates based on mean population estimates for both years.

** Estimates based on the least-squares regression of lower Chena River harvest to upper Chena River harvest.

Table 10. Mean catch rate (Arctic grayling per section) for Age-I and Age-II grayling, and the estimated mean number of Age-III grayling per mile, Chena River Index Sections 2b, 8a, Dam Site, and 10b combined. Least-squares regression predictions for the 1985 Age-II and Age-III values are presented.

Age	Year Sampled 1980	1981	1982	1983	1984	Regression Predictions 1985	Natal Year
I	6.8	27.5	9.3	8.0	28.9		
II	39.0	8.8	47.8	22.6	11.9	50.9	1983
III	194	284	38	262	52	35.3	1982
							1981
							1980
							1979
							1978
							1977

regression was significant ($F = 48.9$, $P < 0.05$). From this regression a predicted CPUE of 50.9 Age-II grayling per day is obtained for 1985. This is well above the previous 5-year mean CPUE of 26 grayling per day. The 90% confidence interval about this estimate is ± 13.3 grayling per day.

The correlation between the CPUE of Age-II grayling and the estimated number of Age-III grayling per mile in the following year was also significant ($r = 0.92$, $p < 0.08$) (Fig. 5b). The slope of the regression was significant ($F = 16.5$, $p < 0.05$), and the regression predicts an estimated 35.3 Age-III fish per mile in 1985 with a 90% confidence intervals of ± 117.1 fish per mile. Although this estimate is not precise (because year-class size is small) the value of 35.3 fish per mile is much lower than the previous 5-year mean of 166 Age-III grayling per mile. Thus, low numbers are predicted in 1985 for both the Age-III and Age-IV classes. Because these two groups make up the bulk of the population, total population sizes may be quite low and the fishery may be quite poor in 1985.

The third recruitment index evaluated the strength of the young-of-the-year age-class using the catch rate obtained from seine hauls in the upper, middle, and lower Chena River. In 1983, a mean catch rate of 30.5 grayling per 100 ft of seine haul resulted in a high 1984 index of Age-I grayling. In 1984, the catch rate was 1.7 grayling per 100 ft of seining on the lower river, 0.04 grayling per 100 ft of seining on the middle river, and 0 grayling per 100 ft of seining on the upper river, for a mean of 0.58 grayling per 100 ft of seining. Obviously, this is a drastic reduction from 1983 ($t = 4.3$, $p < 0.001$), and a very poor 1985 Age-I class is predicted. This low recruitment is probably correlated with the extremely high water conditions encountered in 1984.

Chatanika River:

As with the Chena River, no population estimate of grayling 100-149 mm in length was made because recapture rates were low. Seine hauls for young-of-the-year grayling resulted in a catch rate of 0 grayling per 100 ft of seining.

The CPUE from the index sampling was 23 Age-I grayling per day and 3.7 Age-II grayling per day. As with the Chena River, these recruitment estimates indicate a small young-of-the-year class, a large Age-I class, and a small Age-II class. Again, the year-class strength is probably related to high-water.

Harvest Studies

Upper Chena River:

Results of the 132-day creel census (May 6-September 15) appear in Table 11. During this period, a calculated 17,090 angler hours were expended to harvest 9,623 grayling from the upper Chena River above Mile 26 of the Hot Springs Road. The estimated catch rate was 0.59 grayling caught and kept per angler hour. With catch and release fishing included, the CPUE was 0.81 grayling per hour.

Table 11. Creel-census results of the Arctic grayling fishery on the upper Chena River adjacent to the Chena Hot Springs Road, May 6-September 15, 1984.

Period	Angler* Hours			Number of Fish Kept per Angler Hour	Total Number of Fish per Caught per Angler Hour	Harvest	Mean** Weather Rating	Mean Fork Length (mm)
	Weekday	Weekend	Total					
May 6-31	1,188	2,739	3,927	0.35	0.48	1,390	2.3	318.3
June	1,309	2,376	3,685	0.61	0.94	2,248	2.0	279.7
July	1,675	2,347	4,022	0.25	0.58	1,005	2.2	236.8
August	1,694	2,574	4,268	0.88	1.04	3,756	1.9	282.4
Sept. 1-15	495	693	1,188	1.03	1.08	1,223.6	1.5	249.9
Total	6,361	10,729	17,090	0.59	0.81	9,623		278.0

* Of the anglers, 77.9% were local residents, 7.4% were military personnel, and 14.7% were tourists.

** Weather was rated for each month on a scale of 1-4, where 1 = good and 4 = poor.

Use levels and catch rates were similar to previous estimates. Flooding during much of July, however, resulted in a very low catch rate of 0.25 grayling per hour for that month. In May, both effort and CPUE were not as high as in the past. Again, poor weather and high water were the causes.

As in the past, during every creel census, the weather was rated from 1 to 4, where 1 = very good weather, and 4 = very poor weather (Table 11). The relationship between harvest, catch rate, and the weather rating is quite clear. The months with the best weather rating, August and September, had the highest average catch rates, while May and July, with the poorest weather rating, had the lowest catch rates and harvest.

A summary of upper Chena River creel-census results since 1970 appears in Table 12. Since 1980, the months of May and September have been included in the creel census. The 1984 total of 17,090 angler hours is about 2,000 angler hours lower than the average effort since 1980. One possible explanation for this reduction is the opening of the Chena Lakes Recreation Area, which accounted for an additional 13,000 angler hours of fishing in the Fairbanks area.

For comparison with years before to 1980, creel-census results from June 1 through August 31 were calculated (Fig. 6). The total number of angler hours for this period was 11,975 hours, which is below the previous 9-year mean of 13,511 hours. The harvest, 7,009 grayling, and the catch rate, 0.59 grayling per hour, are both greater than the very low harvest and catch rate in 1983; however, both estimates are less than the previous 9-year mean of 8,668 angler hours and 0.63 grayling per hour.

The mean size of grayling harvested in the fishery was 278 mm. The complete absence of the small Age-III class in the creel, in combination with relatively large contributions by the older age groups, accounts for this very large mean size (Table 13). As in the past, the early-season catch was composed of a large proportion of spawning-size fish. The low catch rate in May, due to high water, reduced the numbers of adult fish harvested. Continued intensive monitoring of this early-season fishery is recommended to ensure protection of spawning stocks.

Badger Slough:

Spot-check angler interviews were conducted on Badger Slough from April 20 to May 31, 1984. The average catch rate was 1.0 grayling caught and kept per angler hour. With catch-and-release fishing included, the catch rate was 1.24 grayling per hour. This catch rate was twice that of the Chena River for the same time period. The higher catch rate for Badger Slough was possibly caused by stable water conditions present in this spring-fed tributary.

A total of 114 angler-caught grayling were measured and scale sampled for aging (Table 14). The mean fork length of grayling caught was 257.8 mm. This is slightly lower than the mean size for angler-caught grayling on the upper Chena River. As with the Chena River, the Age-IV-

Table 12. Summary of creel-census results for the upper Chena River, 1970-1984.

Year*	Date	Days	Total Angler Hours	Total Grayling Harvest	Grayling Caught and Kept per Angler Hour
1970	May 1-31 July 14-Aug. 29	78	12,518	6,770	0.54
1972	May 25-Aug. 27	95	13,116	10,099	0.77
1974	July 1-Aug. 31	62	11,680	18,049	1.55
1975	June 1-Aug. 31	92	22,657	14,067	0.62
1976	June 1-Aug. 31	92	10,762	4,161	0.39
1977	June 1-Aug. 31	92	13,536	9,406	0.69
1978	May 29-Aug. 31	95	10,508	6,898	0.65
1979	June 1-Aug. 31	92	12,744	10,459	0.82
1980	May 8-Sept. 30	144	20,827	16,390	0.78
1981	May 1-Aug. 31	123	15,896	13,549	0.80
1982	May 1-Sept. 15	138	20,379	12,603	0.62
1983	May 1-Sept. 15	138	19,018	10,821	0.58
1984	May 6-Sept. 15	132	17,090	9,623	0.59

* Data before 1982 from Hallberg (1982).

Table 13. Age and length frequencies of 66 Arctic grayling sampled during the upper Chena River creel census, May 6 - September 15, 1984.

Fork Length (mm)	Age					
	IV	V	VI	VII	VIII	IX
190-199	1					
200-209	1					
210-219	3	1				
220-229	3	4				
230-239	0	1				
240-249	0	0				
250-259	1	2	3			
260-269	2	3	1			
270-279			6	1		
280-289			4	1		
290-299			4	1		
300-309				2	2	
310-319				1	4	
320-329				2	2	1
330-339				1	1	
340-349					1	
350-359					1	2
360-369						
370-379						1
380-389				1		
390-399				1		
Percent of Sample	17%	17%	27%	17%	17%	6%
Number	11	11	18	11	11	4
Mean length	226.3	240.8	276.5	318.3	321.7	350.8

Table 14. Age and length frequencies of 110 Arctic grayling sampled during the Badger Slough creel census, April 20 - May 31, 1984.

Fork length (mm)	Age II	III	IV	V	VI	VII	VIII	IX
180-189		1						
190-199	2	0						
200-209		5	1					
210-219		3	1	1				
220-229		5	6					
230-239		1	4	4	1			
240-249		1	6	4	3			
250-259		1	1	5	3			
260-269			1		7	3		
270-279				1	4		1	
280-289			1	2	2	6	1	
290-299					4	6		
300-309				1	1		1	
310-319					1	3		1
320-329						1		2
330-339								
340-349						1		
Percent of sample	1.8%	15.5%	19.1%	16.4%	23.6%	18.2%	2.7%	2.7%
Number	2	17	21	18	26	20	3	3
Mean length	197	218.5	237.3	252.4	270.6	292.4	285.3	321.0
Length range	...	188-251	206-285	210-301	235-312	262-340	274-300	314-326

Table 15. Stocking levels and mean size of pond-reared, hatchery-reared and wild young-of-the-year Chena River Arctic grayling.

Source	Number of Fry Stocked	Mean Fingerling Length (mm)	Number of Fingerlings Stocked	Percent
Mile 32.9 Pit	15,000	138	661	4.4
Mile 33.3 Pit	5,000	132	58	1.2
Mile 38.8 Pit	10,000	133	765	7.7
Mile 45.6 Pit	5,000	0	0	0
Hatchery	92,000	60	0	0
Wild Chena	0	57	0	0

VII classes were all well represented in the catch. About 37% of the harvest included fish of spawning size (greater than 270 mm). In an average year, this would represent a harvest of about 1,700 spawning adults. This is a significant harvest of spawning adults, which should be monitored in the future.

Chena River Stock Enhancement

Need for Enhancement:

With an exploitation rate of nearly 25% and a high total mortality (52%), the Chena River grayling fishery is dependent upon strong recruitment to the Age-III and Age-IV year-classes. Low spawning success or low juvenile survival can result in weak year-classes. Because recruitment estimates can apparently be used to predict upcoming year-class strength, weak year-classes could be strengthened and the fishery improved by stocking. Two enhancement techniques were employed in 1984.

Enhancement Methods:

The first enhancement technique used small winter-kill ponds (ponds that freeze completely during winter) as summer rearing areas for juvenile grayling. The juveniles were then stocked in the open-river system. This technique has been used successfully for the Delta Clearwater River: Age-I pond-reared grayling grew almost to the size of Age-II wild fish (Ridder, 1980).

In 1984, four gravel pits near the Chena Hot Springs Road were experimentally stocked with various numbers of grayling sac fry (Table 15). Growth rates of fish in three of these pits (located at Miles 32.9, 33.3 and 38.8) were quite high. The mean size of these young-of-the-year grayling (135 mm) is well above the mean size of Age-I Chena River wild grayling (97 mm). Growth rates in the fourth pit (mile 45.6) were not determined because flooding occurred and most of the stocked fish escaped.

The accelerated growth rate of these pond-reared fish is needed to supplement poor recruitment from the weak year-class. In order to provide a noticeable improvement in a weak year-class, however, much higher pond-stocking levels will be needed. In 1985, the pits at Miles 32.9, 33.3 and 38.8 will be restocked at higher densities to supplement the low natural recruitment to the Chena River 1984 year-class. In addition, another pit at Mile 43.7 will be stocked for growth evaluation.

In the second enhancement technique, hatchery reared of grayling were stocked in the Chena River. About 92,000 hatchery-reared fish (mean FL, 60.4 mm) were stocked into the Chena River in late August 1984. These hatchery fish were similar in size to the wild young-of-the-year fish, and it was difficult to separate the two groups. In the future, hatchery stocking will be employed only if fish can be grown to more than 90 mm. These fish would be similar in size to Age-I wild fish.

Therefore, as with pond-rearing, these fish could be stocked the year following poor natural recruitment to the young-of-the-year age-class. Even though they would be a year younger, the size of the enhancement fish would be similar to that of the Age-I wild fish.

Stock Separation:

Discriminant Function Analysis. Average length of the pond-reared fish was much greater than that of any of the other three groups (Table 15). Other scale variables related to length (number of circuli and total scale distance) were also much greater for the pond-reared fish. Badger Slough fish were intermediate in length and length-related scale variables, while the hatchery and wild Chena groups had the smallest fish and were quite similar to each other in the length-related variables (Table 16). These length-related variables indicate that Badger Slough and pond-reared fish could be easily separated from the hatchery and wild Chena groups, but that the hatchery and wild Chena groups would be difficult to separate from each other.

The use of these length-related variables in discriminant analysis is not, however, strictly justifiable since the aim of this process is to separate stocks in future years based upon their growth in the first year. Unfortunately, these fish were sampled in late August and early September, prior to the completion of growth during their first summer. Therefore, any additional growth experienced by the general population after the time of sampling would not be reflected in the classification function. However, Walker (1983) noted that young-of-the-year grayling growth rates approached zero in September, and he concluded that additional circuli formation prior to annulus formation was not probable. Therefore, scale analysis was performed both with length-related scale variables and without these variables.

With all length-related variables included in the analysis, three variables (number of circuli, total distance, and distance between the focus and the third circuli) were selected as significant. The LDF classification functions for the four groups are

$$S(H) = -52.5 + 10.33(\text{No.circ}) + 0.91(F3) - 0.29(\text{Total distance})$$
$$S(C) = -48.6 + 9.57(\text{No.circ}) + 0.93(F3) - 0.31(\text{Total distance})$$
$$S(B) = -82.38 + 13.00(\text{No.circ}) + 1.01(F3) - 0.28(\text{Total distance})$$
$$S(P) = -176.58 + 17.37(\text{No.circ}) + 0.73(F3) - 0.05(\text{Total distance})$$

where $\underline{S}$ is the classification score of (H) hatchery, (C) Chena, (B) Badger Slough and (P) pond-reared grayling. Using these classifications, posterior probabilities of membership were quite accurate for Chena, Badger, and Pond grayling (Table 17). However, only 47.1% of the hatchery grayling were correctly classified; the majority of the misclassified fish were assigned to the Chena group. These incorrect classifications were caused by the similarity in size and scale characteristics between the Chena and hatchery fish, as well as the greater variability of size-related factors associated with the hatchery fish (Table 16). The hatchery fish had a bimodal length distribution and consequently, greater variability. Excluding the

Table 16. Mean values and standard deviations of lengths and various scale characteristics for the four groups of young-of-the-year Arctic grayling, 1984.

Scale Variable	Group: Hatchery-Reared $\bar{x}$	Hatchery-Reared SD	Chena River $\bar{x}$	Chena River SD	Badger Slough $\bar{x}$	Badger Slough SD	Pond-Reared $\bar{x}$	Pond-Reared SD
Length of fish (mm)	60.4	8.88	56.4	5.71	86.6	5.67	134.4	6.95
Number of circuli	5.7	1.17	4.6	0.73	8.4	0.92	16.6	1.16
Total distance from focus to outer edge of scale	140.5	28.79	124.8	18.20	207.4	20.41	382.1	38.70
Distance from focus to circulus 1	42.9	9.62	44.0	8.41	53.3	9.97	53.2	10.83
Distance from Circulus 1 to Circulus 2	26.0	4.50	27.2	4.94	30.3	4.93	29.3	6.95
Distance from Circulus 2 to Circulus 3	23.7	4.96	24.0	4.12	26.9	4.76	25.8	5.18
Distance from Circulus 3 to Circulus 4	19.7	4.28	19.5	3.53	20.7	3.17	22.0	5.00
Distance from Focus to Circulus 2	69.0	12.09	71.2	10.74	83.6	11.63	82.5	15.08
Distance from Focus to Circulus 3	92.7	15.24	95.2	12.26	110.4	13.19	108.3	17.88
Distance from Focus to Circulus 4	112.4	17.65	114.6	13.55	131.2	14.15	130.3	20.82

hatchery group from the analysis resulted in 99% of the cases being correctly classified into the Chena, Badger and Pond groups (Table 17). Thus, without hatchery stocking, the 1984 scale analysis with length variables included would have been very useful in stock identification.

Scale variables not related to length of fish included spacing of each circulus between the focus and the fourth circulus, as well as combined distances from the focus to the second, third and fourth circuli. Spacing of circuli between the focus and the fourth circulus was quite similar for the slower-growing groups (Wild Chena and Hatchery) (Table 16). Mean circuli spacings were larger for the Badger and pond-reared grayling than for the other groups, but were quite similar to each other. These variables indicated that separation of Chena and Hatchery grayling from Badger and Pond fish would be possible, but that classification of all four groups was not.

With all the length-related variables excluded, the discriminant analysis was not successful in stock identification. The distance between the focus and the second circulus was the only significant variable. The LDF classifi-cation functions for the four groups are

$$S(H) = -15.27 + 0.40\ (F2)$$
$$S(C) = -16.19 + 0.42\ (F2)$$
$$S(B) = -21.78 + 0.49\ (F2)$$
$$S(P) = -21.24 + 0.48\ (F2).$$

If these discriminant functions are used, only 37% of the fish were classified into the proper group (Table 17). It is then apparent that, without the inclusion of the length-related variables, LDF analysis will not be useful for separation of these four groups.

This is not to say, however, that discriminant analysis based only on scale variable not related to length is not applicable in other grayling stock-separation situations. Walker (1983) had some success with LDF classifications of grayling in Badger Slough and lower Chena River and Ridder (1982) had classification accuracy ranging from 55% to 74% in discriminant analysis of adult grayling from three separate streams. By combining the two slow-growing groups (Hatchery and Chena) and the two fast-growing groups (Badger and Pond), we obtained LDF classification accuracies of near 70%. Again, this indicates that discriminant analysis many be applicable in some grayling stock identification situations where growth factors between the groups are larger enough to produce significant scale-pattern differences.

Circuli Counts. Circuli frequencies of the wild Chena grayling and grayling reared in Clear Hatchery are quite similar (Fig. 7). Badger Slough grayling have intermediate circuli counts and the pond-reared fish have much higher counts.

Because no overlap of circuli counts occurs, separation of pond-reared fish from the other three stocks could be possible based solely on circuli counts (Fig. 7). Ridder (1980-1984) has used this technique for stock separation of Delta Clearwater grayling that were pond reared.

Table 17. Linear Discriminant Function classification matrix of young-of-the-year Arctic grayling, 1984.

Group	Percent Correct	Number of Cases Classified into Groups: Hatchery	Chena	Badger	Pond
ALL VARIABLES INCLUDED IN ANALYSIS					
Hatchery	47.1	48	43	11	0
Chena	86.1	10	62	0	0
Badger	96.2	3	0	75	0
Pond	100.0	0	0	0	167
Mean percent correct = 84.0.					
HATCHERY GROUP EXCLUDED					
Chena	97.2	...	70	2	0
Badger	100.0	...	0	78	0
Pond	99.4	...	0	1	166
ONLY VARIABLES NOT RELATED TO LENGTH INCLUDED IN ANALYSIS					
Hatchery	53.9	55	11	11	25
Chena	27.8	29	20	9	14
Badger	46.2	11	10	36	21
Pond	26.3	36	20	67	44
Mean percent correct = 37.0.					

Based on this study, in future years any grayling with more than 11 circuli between the focus and the first annulus will be identified as a pond- reared, enhancement grayling. This technique does not take into consideration additional circuli formation after the time of sampling, but, in the case of the pond-reared fish, the separation is so great that additional growth should create little overlap in circuli counts.

Walker (1983) demonstrated that young-of-the-year grayling from Badger Slough were consistently larger than those from the main Chena River stocks. Based on back-calculated sizes at Age-I, he concluded that Badger Slough provided significant recruitment to the Chena River. This larger size of Badger Slough fish is reflected in circuli counts to the first annulus (Fig. 7). Unfortunately, considerable overlap exists with circuli counts of lower Chena River fish. These overlaps could be further complicated by increased growth and circuli formation in the early fall.

To test the hypothesis that additional circuli formation does not occur after early September, we compared the frequency distribution of first-annulus circuli counts of Age-IV grayling (natal year 1980) captured during the Badger Slough spring fishery with those of young-of-the-year samples obtained in 1981 (Walker, 1983), 1982 (Walker, 1983), and 1984 (Fig. 8). Results were inconclusive: the 1980 young-of-the-year sample was not significantly different from the 1984 young-of-the-year sample ($x^2 = 9.24$, $P > 0.05$); however, differences between the 1980, 1981 and 1982 young-of-the-year samples were significant ($x^2 > 80$, $P < 0.05$). These results indicate various possibilities: young-of-the-year growth rates may vary from year to year in Badger Slough, additional growth or circuli formation can occur in September, or the larger and faster-growing fish survive better than the slower-growing fish.

These first-annulus circuli counts provide some support to the theory of grayling homing to natal streams because the average circuli count of the Age-IV Badger Slough fish was much greater than would be expected from fish that were spawned in any other river section. The average first-annulus circuli counts and standard deviations for Chena River and Badger Slough fish are listed in Table 18. Analysis of variance found a significant difference in mean counts between these Sections ($P < 0.05$; $F = 10.3$). Student-Newman-Keuls (SNK) multiple range comparisons were significant between Badger Slough mean circuli counts and all the other sections ($P < 0.05$) except Section 2b ($P > 0.05$; $q = 2.04$). This again indicates that the Badger Slough fish may be a separate spawning stock. Why circuli counts from Section 2b were not significant is unknown. Perhaps migration of Badger Slough grayling into this section caused the observed overlap in circuli counts. A micro-wire tagging experiment of young-of-the-year Badger Slough fish will be initiated in 1985 to help explain the importance of Badger Slough as a spawning stream and to verify homing to natal streams.

Movements and Migrations

Tagging Study:

This study was initiated in June 1980 to increase understanding of

Table 18. Mean, standard deviation, and range of scale-circuli counts of Age-IV Arctic grayling sampled in the Chena River, Badger Slough and Chatanika River, 1984.

Number of Circuli	Sample Area						
	2b	8a	Dam Site	10b	12	Badger Slough	Chatanika River
Mean	8.16	7.68	7.16	7.26	6.28	8.67	5.52
Standard deviation	1.06	0.99	1.22	1.34	1.43	1.96	1.17
Range	6-12	6-10	6-12	4-11	4-9	6-13	4-9

intrastream movements of Chena River grayling and the importance of movements in sustaining catch rates in high-use fisheries.

No additional tagging was performed in 1984 and only 42 tags were recovered. After one more summer of recapture effort, all data will be analyzed for movement trends over a 5-year period.

Radio-Tagging:

Small surgically-implanted radio transmitters were tested on eight Chena River grayling in 1983 and 1984. The purpose was to determine the feasibility of this method for use on small fish, such as grayling. It was hoped that radio-tagging would be useful in the future for pinpointing overwintering and spawning areas and documenting movement and stock mixing.

Results were mixed. The actual tagging operations went well, and the grayling appeared to behave normally after release. All fish tagged in the spring moved upstream, and those tagged in the late summer moved downstream, as would be expected.

The major problem was with tag life. Two tag types were tested: one with a 7-to 8-month projected life, and one with a 3-month life. The 3-month tags lasted an average of 70 days; the first two 7-month tags went dead after only about 1 month. It was thought that water damage was the cause.

Two more 7-month tags were tested. These had a slightly thicker covering to prevent water seepage. These tags lasted an average of 130 days. Although much less than the expected tag life, 4 months is enough time to document winter movements of grayling tagged in the late fall. Therefore, additional telemetry on the Chena and Salcha Rivers is proposed to map overwintering areas using these 7-month tags.

Stream Surveys

Little Chena River:

A preliminary survey of the grayling population composition of the lower 10 mi of the Little Chena River was performed in June 1984. The lower Little Chena River is a slow, meandering creek with steep sides and a mud and gravel bottom. The average depth is about 3.5 feet. Siltation from placer mining in the upper river makes the Little Chena River very turbid (Secchi disk reading, 4 in).

Grayling were sampled with 30-ft graduated-mesh (0.5, 0.75- and 1-in mesh panels) gill nets. In 6 net nights, 40 grayling (mean length, 219.6 mm) were captured. None of the grayling were of spawning size. Back-calculated lengths at each annulus were consistently smaller ($P < 0.05$) than length-at-age values for Chena River grayling (Table 19). This reduced growth rate of Little Chena grayling could possibly be caused by mining siltation. These data are preliminary and are subject to bias because of small sample size and problems with using

Table 19. Mean Lengths-at-Age and Standard Deviations for 436 Arctic Grayling from the Chena River and 41 Arctic Grayling from the Little Chena River. Lengths-at-Age for the Little Chena River Fish Were Back-Calculated.

River	I		II*		III*		IV*		V*		VI		VII	
	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD
Chena	97	13.4	152.6	12.0	181.8	12.1	213.2	18.4	225.6	17.0	257.2	15.2	274.7	14.7
Little Chena	97.5	14.0	131.0	16.5	165.6	16.2	200.8	18.8	210.9	21.1	248.8	8.3	265.5	19.1

* Mean lengths at this age were significantly different ($P < 0.05$) for Chena River fish and Little Chena River fish.

back-calculated length; however, they indicate that siltation may have a detrimental effect on fish, such as grayling, which rely on sight for feeding.

Tack (1972) surveyed the upper sections of the Little Chena River from Sorrels Creek to the Chena Hot Springs Road bridge. Above the influence of mining siltation (at Fairbanks Creek), he found grayling fry. He also found larger fish in area with silty water but was unable to capture them with hook and line.

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