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Contributions of Arctic Grayling from Caribou Creek to the Richardson Clearwater River and Shaw Creek, 1980 through 1988

by

William P. Ridder

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Alaska Department of Fish and Game

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ABSTRACT

The proportion of Arctic grayling ≥ 270 millimeters fork length that emigrate from Caribou Creek after spawning to the Richardson Clearwater River, and are subsequently harvested the following year in the spring fishery in the Tanana River at Shaw Creek, was estimated for 1980 - 1988. On average, 67% of the population in the Richardson Clearwater River was comprised of Arctic grayling from Caribou Creek during the same year. On average, 48% of the pre-spawning aggregation of Arctic grayling in the Tanana River at Shaw Creek were from Caribou Creek one year previous. On average, 73% of post-spawning emigrants from Caribou Creek were from Caribou Creek one year previous. Although these results are not conclusive, they do indicate that a majority of Arctic grayling in the Richardson Clearwater River are from Caribou Creek. Similarly, a majority of Arctic grayling potentially harvested in the spring fishery at Shaw Creek could be from Caribou Creek, necessitating careful management of this fishery to prevent declines in abundance at the Richardson Clearwater River. Contributions of Arctic grayling from Caribou Creek back to the same creek one year later indicate that homing to this spawning area occurred. Future research should focus on quantification of contributions to the Richardson Clearwater River from streams other than Caribou Creek, and development of a management plan for Arctic grayling in this area of the Tanana River drainage that allows for sustainable harvest of Caribou Creek fish in the Shaw Creek and Richardson Clearwater River fisheries.

KEY WORDS: Arctic grayling, *Thymallus arcticus*, contribution rate, abundance, spawning, migrations, mixed stock fisheries, Alaska, Shaw Creek, Richardson Clearwater River, Caribou Creek, Tanana River drainage.

INTRODUCTION

Riverine stocks of Arctic grayling *Thymallus arcticus*, hereafter referred to in the text as grayling, in the Tanana River drainage of interior Alaska commonly exhibit seasonal inter- and intrastream movements as a behavioral strategy for survival (Tack 1980). Through these movements, grayling utilize a variety of habitats for different life stages (Armstrong 1982). Some large rivers offer all habitat types for a particular grayling population and movements are predominantly intrastream (e.g., stocks in the Chena and Chatanika rivers). Populations inhabiting other large river systems, which seemingly afford all the necessary habitat, have a component of the population that exhibits interstream movements (e.g., the stocks in the Salcha and Goodpaster rivers (Ridder 1991)). Movements of grayling out of these rivers are typically to summer feeding (spring-fed systems) and overwintering areas (the Tanana River). Interstream movements are particularly important for grayling populations that utilize small drainages, in which habitat is seasonally unsuitable for all of the fish's life cycle. These populations typically use two or more river systems for spawning, rearing, and overwintering (e.g., stocks of Shaw Creek (Ridder 1991) and Piledriver Slough (Douglas Fleming, Alaska Department of Fish and Game, personal communication)). While the habitat of these various river systems are dramatically different from one another, each is optimum, or at least available, for utilization by grayling during a particular season or life stage. Interstream movements can confound stock assessment data, subsequently biasing estimates of dynamic rates, and reducing the efficacy of management actions. While movements of grayling in the middle Tanana River drainage have been identified (most recently by Ridder 1991), the magnitude of movements expressed in terms of contributions to receptor river systems have not been investigated prior to this study. This report provides estimates of the proportion of fish that are subsequently found in the Richardson Clearwater River during summer after emigrating from Caribou Creek after spawning that same year. In addition, estimates of contribution to the spring fishery at the mouth of Shaw Creek one year later are presented. Hopefully, these estimates will inspire further inquiries into interstream movements of grayling in the Tanana River drainage.

The specific objective of this report was to estimate the relative contribution of grayling greater than 269 mm fork length (FL) that were marked and released at Caribou Creek in year i and recovered in year i in the Richardson Clearwater River and in year i+1 in Shaw Creek during 1980 through 1988. Since the number of fish marked and released in Caribou Creek varied by year, estimated contribution rates could be severely biased if the proportion of marks in the emigrating population were not constant among years. Thus to estimate the yearly proportion of marked fish, annual abundance estimates were developed for the Caribou Creek population.

Studies of the Delta and Richardson Clearwater rivers (Figure 1) have shown that few, if any, grayling spawn or overwinter in these streams (Reed 1961, Roguski and Shallock 1967, Tack 1980, Peckham and Ridder 1979). Yet both rivers offer popular fisheries for large grayling during summer months. Immature (< 270 mm FL) grayling immigrate to the Delta and Richardson Clearwater rivers as early as April, followed by spent adults (≥ 270 mm FL) in May and June (Ridder 1981 - 1985). Grayling are nearly absent in these

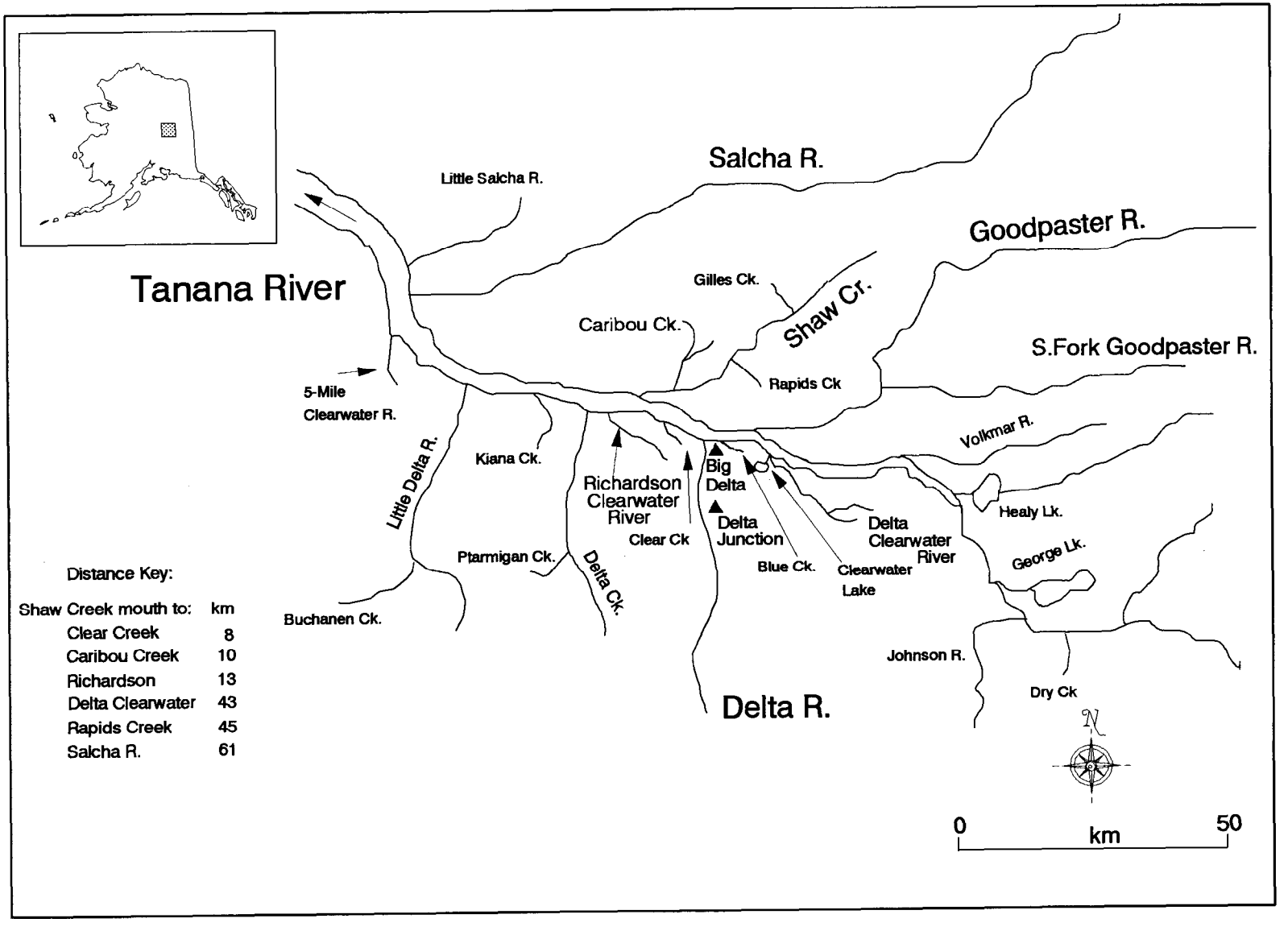

Figure 1. Map of the Middle Tanana drainage and sampling locations.

streams from October through March. Ridder (1991) documented the annual return (i.e. homing) of grayling to these summer feeding areas. Reed (1961) and Tack (1980) suggested that the use of these streams as summer feeding areas is a result of a mix of movements of immature and adult grayling from overwintering and spawning areas. Grayling tagged in the Goodpaster, Salcha, and Volkmar rivers and Shaw Creek (Figure 1), which they referred to as donor streams, have been commonly recovered in the spring-fed systems (Ridder 1991). The individual importance of these donor streams to the level of abundance in these spring-fed systems was not known. Investigations of likely donor (spawning) streams were initiated in the middle Tanana River drainage surrounding Delta Junction (Figure 1) in 1979 and continued through 1987 (Peckham and Ridder 1980; Ridder 1981, 1982, 1983, 1984, 1985, 1989, and 1991; Holmes et al. 1986; Clark and Ridder 1987, 1988). These investigations focused predominantly on Caribou Creek, a tributary of Shaw Creek. Additionally the studies included yearly monitoring of population composition and abundance in the Richardson Clearwater River and of grayling harvest, fishing effort, and composition of the harvest in the spring fishery at Shaw Creek.

Shaw and Caribou Creeks

Shaw Creek is a tannic stained, bog-fed stream, 112 km in length and located 32 km northwest of Delta Junction (Figure 1). By midwinter, the creek freezes solid in shallow areas, and upriver pools become anoxic. Two of six tributaries to Shaw Creek are known to provide spawning habitat for grayling. Between 1979 and 1988, 8,000 grayling were tagged and released in the Shaw Creek drainage. The majority were tagged in June as they emigrated from Caribou Creek, a major tributary of Shaw Creek, after spawning. Angler returns of 780 of these tags came from six recreational fisheries within 72 km of the mouth of Shaw Creek, ranging from the Little Salcha River downstream to the Delta Clearwater River upstream (Figure 1, Ridder 1991). Based on limited tag recapture-to-catch ratios, Ridder (1985) estimated that fish from Caribou Creek accounted for 30 to 50% of grayling abundance in the Richardson Clearwater River.

The recreational fishery at Shaw Creek occurred in April over a span of 4 to 11 days[1]. This brief and concentrated fishery targeted grayling congregating in the Tanana River, adjacent to the mouth of Shaw Creek, awaiting ice break-up. Creel surveys conducted from 1981 through 1986 found that harvests consisted of greater than 80% mature, pre-spawning grayling and ranged from 4,343 fish in 1981 to 270 fish in 1986 (Table 1, Figure 2, Appendices A1, A2.1, and A2.2). Annual harvests of grayling for the entire fishing season ranged from 2,584 fish in 1985 to 111 fish in 1992 (Mills 1984-1994; Table 1). From 1983 through 1986, the harvest during April accounted for an average of 58% of the total annual harvest. Annual fishing effort for all species (small fisheries also exist for burbot, *Lota lota*, and northern pike, *Esox lucius*) has ranged from 2,495 angler-days in 1983 to 488 angler-days in 1989 and has averaged 1,203 angler-days (Table 1). The majority of angling effort occurs in the lower 1.6 km of Shaw Creek.

[1] The spring fishery was closed by regulation (1 April through the first Saturday in June) beginning in 1987. Emergency Order closures were in effect in 1981 (23 April - 15 May) and 1985 (1 - 15 May).

Table 1. Estimated Arctic grayling abundance, harvest, and angling effort in Shaw Creek, 1981 - 1993.

			Harvest		Effort	
Year	Abundance[a]	SE[b]	Season[c]	Spring[d]	Season[c,e]	Spring[d]
1980	NA[f]	---	NA	NA	NA	NA
1981	27,509	7,708	NA	4,343[g]	NA	966
1982	20,297	4,863	NA	979	NA	555
1983	12,267	3,010	2,297	1,864	2,495	874
1984	13,994	5,767	2,570	913	2,195	1,095
1985	14,812	7,370	2,584	1,533[g]	1,248	372
1986	78,596	50,021	505	270	2,003	479
1987[h]	6,080	3,596	567	closed	797	closed
1988	NA	---	873	"	564	"
1989	NA	---	411	"	488	"
1990	NA	---	203	"	1,452	"
1991	NA	---	453	"	773	"
1992	NA	---	111	"	491	"
1993	NA	---	383	"	732	"
Averages	NA	---	996	1,650	1,203	724

[a] Abundances estimated from the Jolly-Seber model for grayling ≥200 mm FL in 1981 - 1986 (Clark and Ridder 1988) and for grayling ≥270 mm FL in 1987 (Ridder 1989).
[b] SE = standard error of the abundance estimate.
[c] Data sources: for 1983-1987 and 1989-1993, Mills (1984-1994); for other years, Mills (unpubl.).
[d] Data sources for spring fisheries: 1981-1984, Ridder (1982-1985); 1985, Holmes et al. (1986); 1986, Clark and Ridder (1987). Effort pertains to grayling fishery.
[e] Effort is the number of angler-days expended for all fish species.
[f] NA = data is either not available, not collected, or not applicable.
[g] Spring fishery closed by Emergency Order: 23 April - 15 May 1981; 1 - 15 May 1985.
[h] Fishing regulations changed from no size limit to a 12" minimum size limit and from no closed season to a spring closure (1 April though the first Saturday in June).

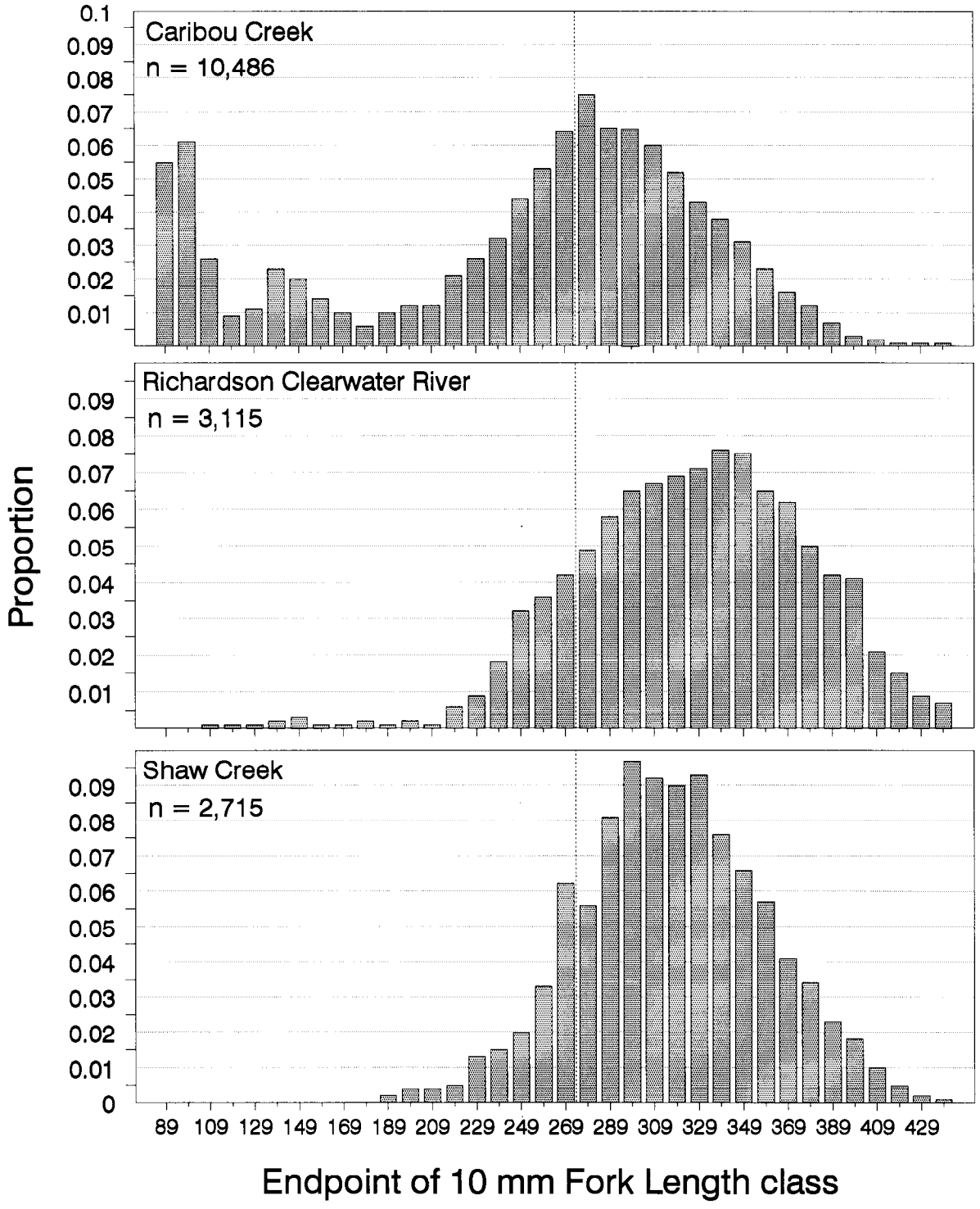

Figure 2. Length frequencies for all Arctic grayling sampled during the June outmigration from Caribou Creek 1980 - 1987, in April at the mouth of Shaw Creek 1981 - 1988, and in July in the Richardson Clearwater River 1980 - 1988.

Estimates of grayling abundance adjacent to the mouth of Shaw Creek have ranged from 6,080 fish (SE = 3,596) ≥270 mm FL in 1987 to 78,596 fish (SE = 50,021) ≥200 mm FL in 1986 (Table 1). These abundance estimates were considered biased high due to mixing of stocks in the Tanana River and to lack of recoveries of small grayling (Clark and Ridder 1988).

Caribou Creek, approximately 26 km long, is located 10 km upstream of the mouth of Shaw Creek. Caribou Creek is small, averaging 6 m wide with an average depth and discharge of 46 cm and 0.52 m^3/s, respectively, at the confluence with Shaw Creek. Harvest and angling effort in Caribou Creek is negligible. From 1980 through 1987, grayling were sampled each June as they emigrated from Caribou Creek. The size composition of the emigration included all sizes (and ages) of grayling except fish between 120 and 230 mm FL (Figure 2, Appendices B1.1 and B1.2). Mature and spent grayling comprised from 25 to 70% of the emigration. The majority of grayling ≥200 mm FL were tagged with anchor tags. While recoveries of these tags were subsequently made in six other river systems, same year recoveries of an immature fish and one spent adult were also made in June in Gilles Creek, a Shaw Creek tributary 70 km above Caribou Creek, and indicated that not all Caribou Creek adult emigrants leave the drainage (Ridder 1991).

Richardson Clearwater River

The Richardson Clearwater River arises from springs located on the southern floodplain of the Tanana River, 3 km west of Big Delta (Figure 1). The river is 19 km in length and enters the Tanana River 13 km downstream of Shaw Creek. As with other spring-fed systems in the drainage, most notably the Delta Clearwater River, the Richardson Clearwater River can be characterized by its clear and cold water, stable discharge (3 - 7°C and 8.5 - 11.3 m^3/s, respectively). Access is limited to riverboats via the Tanana River and to small float planes on the Richardson Clearwater. The nearest boat launch is at Shaw Creek. There are 21 cabins on the river. The river supports a recreational fishery for grayling and little angling effort is directed at other available species (round whitefish, *Prosopium cylindraceum*, coho salmon, *Oncorhynchus kisutch*, and chum salmon, *Oncorhynchus keta*). The grayling fishery can be characterized as "blue ribbon" due to the availability of large fish, high density of fish, esthetic qualities of the river, and lack of direct road access. From 1981 through 1993, harvests have ranged from 2,822 to 251 grayling and averaged 1,048 (Table 2). Angling effort has ranged from 1,365 to 255 angler-days with an average of 934 (Table 2). The majority of angling occurs in the lower 9.6 km of river.

Catch per unit effort (CPUE) statistics and age, length, and weight samples were taken annually in the Richardson Clearwater River from 1976 through 1988. From 1980 through 1988, sample methods, timing, and area were held constant and occurred in July in three contiguous study sections. CPUE statistics were considered a relative index of the population's abundance and ranged from 324 grayling-per-electrofishing-pass in 1982 to 65 grayling-per-electrofishing-pass in 1986 (Table 2). These indices showed a high correlation to abundance estimates from mark-recapture experiments performed in the upper study section (Section 3), from 1982 through 1988 and in the combined study area (whole river) from 1985 through 1988 ($r = 0.98$ and 0.91, respectively, Ridder 1989).

Table 2. Estimated Arctic grayling abundance (relative and absolute[a]), harvest, and angling effort in the Richardson Clearwater River, July, 1980 - 1993.

	Whole River					Section 3[b]		
	Abundance			Fishery[c]		Abundance		
Year	Relative	Absolute	95% CI	Harvest	Effort[d]	Relative	Absolute	95% CI
1980	170	NA[e]	---	NA	NA	NA	NA	---
1981	167	NA	---	1,562	916	NA	NA	---
1982	324	NA	---	1,729	1,365	203	5,340	3,028 - 10,680
1983	220	NA	---	2,822	1,349	103	1,792	1,016 - 3,460
1984	138	NA	---	1,376	1,080	101	2,076	1,148 - 4,520
1985	142	3,114	1,939 - 4,289	798	902	83	1,610	974 - 2,876
1986	65	1,418	786 - 2,837	827	596	30	468	191 - 1,170
1987[f]	113	2,775[g]	1,653 - 3,896	251	724	69	1,368[g]	476 - 2,260
1988	187	4,599[g]	3,127 - 6,071	509	255	127	2,193[g]	1,274 - 3,112
1989	NA	NA	---	972	1,364	NA	NA	---
1990	NA	NA	---	523	518	NA	NA	---
1991	NA	NA	---	1,419	1,199	NA	NA	---
1992	NA	NA	---	436	1,355	NA	NA	---
1993	NA	NA	---	405	514	NA	NA	---
Averages	170	NA	---	1,048	934	102	NA	---

[a] Data is from Ridder 1989. Relative abundance is the total catch of Arctic grayling made in the first electrofishing run through a section (river). Absolute abundance is a mark-recapture (Petersen) estimate.

[b] Section 3 is the upper 3.2 km of the navigable portion of the Richardson Clearwater River.

[c] Data sources: for 1986 and 1989-1993, Mills (1984-1994); for other years, Mills (unpubl.).

[d] Effort is the number of angler-days expended for all fish species.

[e] NA = data is either not available, not collected, or not applicable.

[f] Fishing regulations changed from no size limit to a 12" minimum size limit and from no closed season to a spring closure (1 April though the first Saturday in June).

[g] Estimate is for fish greater than 249 mm FL.

Whole river abundance estimates ranged from 4,599 grayling in 1988 to 1,418 grayling in 1986 (Table 2).

The sampled population is predominantly comprised of adult and immature grayling that migrate into the river beginning in mid-May from spawning areas in other rivers (Appendices C1.1 and C1.2). Three of these spawning areas have been documented from tagging studies: Caribou and Rapids Creek in the Shaw Creek drainage and the Goodpaster River (Ridder 1991). The average size of grayling in the Richardson Clearwater River is skewed towards larger fish in relation to fish sampled at Shaw Creek (Figure 2).

METHODS

Data Collection

The data in this report represents a portion of that collected in the aforementioned studies of the Richardson Clearwater River and Shaw and Caribou creeks over a nine year period, 1980 through 1988. These studies employed relatively consistent methodologies and objectives. The original data, which have been archived in standardized ASCII databases (Ridder 1991; Appendix D1), were truncated for this report to include only fish greater than 269 mm FL. Truncation was done for the following reasons:

1) movements of fish of different maturity (fry, juvenile, and adult) may differ (Tack 1980, Ridder 1991);

2) previous attempts at abundance estimation at Shaw and Caribou creeks for fish greater than 200 mm FL were severely biased due to lack of recaptures of smaller sized fish (Clark and Ridder 1988, Ridder 1989);

3) the length at maturity for 50% of the population was 279 mm FL (Clark 1992);

4) fisheries in the Richardson Clearwater River and Shaw Creek predominantly catch fish greater than 269 mm FL (Holmes et al. 1986; Ridder 1989);

5) regulations enacted in 1987 limited harvests to fish greater than 269 mm FL in Shaw Creek and the Richardson Clearwater River; and,

6) Caribou Creek sampling occurred during a post-spawning migration that included adult fish.

After truncation, tagging histories, stratified by year of release, were constructed for each marked fish released at Caribou Creek. For each year, recaptures of these fish were tabulated for each sample specific to year of release and recapture location (Appendices A, B, and C). This study treats both newly tagged and previously tagged fish released in any year as members of one cohort that is the population emigrating from Caribou Creek in year i.

Caribou Creek:

Grayling were captured with a fyke trap in 1980 and a weir in 1981 through 1987. Each gear type blocked the creek to the majority of migrants except during periods of high water. During low water conditions, seining was sometimes employed to drive grayling into the downstream trap. All gear types used 9.5 mm meshes. Both immigrating and emigrating fish were captured in 1980 through 1982 while only emigrants were captured from 1983 to 1987. For the former three years, the small number of immigrants greater than 269 mm FL (n = 40, 10, and 71, respectively) are included in this study under the assumption that they would emigrate out of the creek after spawning. Recaptures of fish tagged during immigration were commonly made during the emigration in 1980 though 1982 (Ridder 1983). In all years, with the following exceptions, sampling for emigrants was continuous and scheduled for the first three weeks of June (Table 1). In 1983, the weir was closed for a two day period (6 through 8 June) and in 1984 and 1985 sampling was curtailed early due to high water flooding the weir. Based on observations from 1980 through 1982, in which large numbers of grayling remained above the weir at the end of sampling (Ridder 1982) and the high water events, it is assumed that in no year were all emigrating fish sampled.

Richardson Clearwater River:

Grayling were collected in July with an electrofishing boat using an AC pulsator from 1980 to 1986 and a DC pulsator in 1987 and 1988 (Ridder 1989). Sampling consisted of one downstream pass through the lower 13 km of the river (1 unit of effort). The total catch of grayling per downstream pass (CPUE) was used as an annual index of relative abundance. Additional electrofishing and hook and line sampling were used in mark/recapture (M/R) experiments in the upper 3.2 km in 1982 through 1984 and in the entire 13 km reach in 1985 through 1988. The additional M/R samples in 1982 and 1983, which included recaptures of tagged Caribou Creek grayling, were not used in this report since lengths of these fish were not recorded.

Shaw Creek and Tanana River:

In the Tanana River adjacent to the mouth of Shaw Creek, grayling were sampled from angler creels during the April fishery in 1981 through 1986 (Clark and Ridder 1987). Sampling was done in conjunction with a creel survey for a single exit fishery. In all years except 1981, the grayling kept by interviewed anglers was measured for length and tag recaptures noted. In 1981, 181 of the sampled harvest of 471 fish were not measured unless they had tags. The tagged fish were assumed to have the same length frequency as the sampled fish. With the fishery closed by regulation beginning in 1987, a pulsed-DC electrofishing boat was used during the same time period in 1987 and 1988 to gather samples for continuation of the Jolly-Seber estimator for Shaw Creek (see Clark and Ridder 1988; Ridder 1989).

Regardless of location and capture method, with the exceptions noted above, all captured grayling were measured to the nearest 1 mm FL. In Caribou Creek (1980 through 1982 and 1984 through 1987) and Shaw Creek (1987 and 1988), grayling greater than 200 mm FL were tagged with an individually-numbered Floy internal anchor tag. A double finclip was used as the primary mark in 1983 at Caribou Creek. Secondary marks (finclips) were also used in 1982 at Caribou

Creek. Date, location, fork length, finclip, tag number, and gear type were recorded for individual fish at all locations.

Estimation of Abundance in Caribou Creek

Abundance of grayling (≥270 mm FL) in Caribou Creek was estimated for the years 1980 through 1986 using the modified Petersen formula of Robson and Flick (1965) that culls recruitment between two sample events. Sample events occurred at one year intervals. A low number of recaptures during sampling in 1985 prevented calculation of an abundance estimate for 1984.

Since the Petersen estimator allows for recruitment or mortality between sample events but not both, the nonparametric method of testing and culling growth recruitment was used (Robson and Flick 1965). The Robson-Flick technique uses the range of unique lengths (cells) of recaptured fish from the mark event as boundaries for a length frequency distribution of unmarked fish in the recapture event. By both plotting the running averages of these length frequencies (Appendices E1 through E6) and performing a series of hypothesis tests in program FLICK (Bernard and Hansen 1992), the cell (length range) where recruitment is no longer significant was determined. The running average of unmarked fish in this cell was used in place of the catch component of the Petersen estimator resulting in an abundance estimate applicable to the year of the first (mark) event.

The necessary assumptions for a reliable abundance estimate are (from Seber 1982):

1) all grayling in the target population have the same probability of being caught in the ith sample;

2) all grayling in the target population have the same probability of surviving from the ith to the $(i+1)$th sample;

3) all grayling caught in the ith sample have the same probability of being marked and released alive into the population;

4) all marked grayling do not lose their marks and all marks are reported on recovery; and,

5) all samples are instantaneous and each release is made immediately after the sample.

Assumptions 1 and 2 are central to reliable parameter estimation. Differences in capture probability can be related to size selective sampling due to either the availability of different sized fish (behavioral differences) or gear selectivity. Yet, if marked fish mix completely with unmarked fish between the ith and $i+1$ sample, assumption 1 can be violated without biasing the estimate. The year interval between events and the fact that sampling occurred on a population in transit would appear to ensure mixing. However, changes in the probability of capture cannot be separated from changes in survival rate. So, these assumptions were subjected to testing as described below.

The Robson-Flick model provides unbiased estimates of abundance when the first event sample is not size selective (Bernard and Hansen 1992). To test this assumption, two Kolmogorov-Smirnov (KS) two-sample tests were performed to compare length distributions of marked fish from the first event versus unmarked fish captured in the second event and of marked fish versus the recaptured fish in the second event to evaluate size selectivity. To alleviate the problem of growth between events, lengths at tagging for recaptured fish were used in the first KS test. Plots of the KS tests are found in Appendices E1 through E6. The first KS test provided an inference whether bias may exist in the two events. The second KS test provided an inference whether the bias occurred during the second event. If the first test was significant and the second was not, then the recapture event was unbiased while the first event was biased. With the Robson-Flick estimator requiring an unbiased first event, an insignificant test between marked and unmarked fish was mandatory.

Assumption 3 was assumed to be valid for all of the seven years it was used, excepting the 1983 and 1984 samples. In 1983 at Caribou Creek, all fish greater than 199 mm FL were released with a double finclip but were not tagged. In the recapture event one year later, growth of these fish complicated the decision of which finclipped recaptures were in the 1983 target population (≥270 mm FL) and which recaptured fish were not. A mean annual growth increment was determined through comparisons and hypotheses testing between the finclipped recaptures and the tagged recaptures from 1981 through 1983 (Appendix B2). A growth increment of 15 mm was chosen based on similarities between the finclipped recaptures and the recaptures of 132 fish tagged in 1982. This growth increment was added to the minimum size of the target population, 270 mm, and all finclipped recaptures that were ≥285 mm FL in 1984 were considered recaptures. These finclipped recaptures were used in the 1983 Robson-Flick model. In regards to the 1984 sample, 49% of the catch were tagged and released (308 marks released from a catch of 632, Appendix B3). The Robson-Flick model could not be used with the 1984 data due to insufficient recaptures (n = 3) in 1985.

Assumption 4 was violated since double marking was not employed in all but the 1982 sample. Mark loss (tag shedding) has been estimated for grayling at an annual rate of 8% in Caribou Creek (Ridder 1984). The failure to acknowledge marked fish would bias abundance estimates high. To estimate this bias, the Robson-Flick model was applied to the 1982 data with and without accounting for tag loss. With tag losses (n = 13) included in the recaptures provided that they were at least 285 mm FL, the 1982 abundance was 6,134 with a standard error (SE) of 653 and a coefficient of variation (CV) of 10.6%. Without the accounting for tag loss, the abundance was 6,495 with a SE of 666 and CV of 10.3%. Thus a failure to detect marks in 1982 resulted in an overall 6% bias in estimates of abundance, proportion marked, and contributions to Shaw Creek and the Richardson Clearwater River. This bias was considered insignificant and an adjustment to number of recaptures was not attempted for any estimate.

While sample events ranged from 8 to 25 days and averaged 15 days (Appendix B3), assumption 5 was considered met. The violation of the assumption would introduce bias from differential mortality among those fish

tagged at the onset of sampling and those tagged at the end of sampling. This bias is considered insignificant.

During data analysis it was necessary to partition abundance estimates from the three waters to fish greater than 269. The abundance of this population component was estimated with:

$$\hat{N}_a = \hat{p}_a(N) \qquad (1)$$

where:

$\hat{N}_a$ = the estimated abundance of grayling of component a; and,

p_a = the proportion of component a from equation 9.

The variance of the product N_a was estimated using Goodman's (1960) exact variance of a product:

$$\hat{V}[\hat{N}_a] = \hat{N}^2\hat{V}(p_a)+p_a^2\hat{V}(N)-\hat{V}(p_a)\hat{V}(N) \qquad (2)$$

Estimation of Contribution Rate

Proportional estimates of marked grayling (≥270 mm FL) in each year (*i*) for the emigrating adult population at Caribou Creek were used in conjunction with the proportions of these marked fish in samples (≥270 mm FL) from the Richardson Clearwater River in year *i+h* and from Caribou and Shaw creeks in year *i+h* to estimate the contribution of Caribou Creek fish outmigrating in year *i* over a series of years.

From abundance estimates, the proportion of fish marked in Caribou Creek in year *i* was estimated by:

$$\hat{p}_t = \frac{m_t}{\hat{N}_t} \qquad (3)$$

where:

$\hat{p}_t$ = the estimated proportion of grayling marked in Caribou Creek;

m_t = the number of unique grayling marked in Caribou Creek; and,

$\hat{N}_t$ = the abundance of grayling in Caribou Creek.

The variance of p_t was approximated by:

$$\hat{V}[\hat{p}_t] \approx \frac{\hat{m}_t^2 \, \hat{V}[N_t]}{\hat{N}_t^4} \qquad (4)$$

where: $\hat{V}[N_t]$ = the variance of abundance of grayling in Caribou Creek.

Upon recovery, the proportion of marked fish in the Shaw Creek spring fishery, the Caribou Creek out-migration, and the Richardson Clearwater River was the ratio of marks to those examined for marks:

$$\hat{p}_m = \frac{c_m}{n_m} \qquad (5)$$

where: $\hat{p}_m$ = the estimated proportion of grayling marked in Caribou Creek and recovered in area *m*;

c_m = the number of marked grayling from Caribou Creek that are recovered in area *m*; and,

n_m = the number of grayling examined for marks in area m in year *i+h*.

The variance of p_m was the variance of a binomial, or:

$$\hat{V}[\hat{p}_m] = \frac{\hat{p}_m (1 - \hat{p}_m)}{n - 1} \qquad (6)$$

The contribution rate of fish from Caribou Creek that was relative to the adult population in Caribou and Shaw creeks and the Richardson Clearwater River was estimated with:

$$\hat{p}_c = \frac{\hat{p}_m}{\hat{p}_t} \qquad (7)$$

Variance of the contribution rate was approximated with the Delta method (Seber 1982; ignoring the hat symbols, all quantities were estimated)

$$V[p_c] \approx \left[\frac{p_m}{p_t}\right]^2 \left[\frac{V[p_m]}{p_m^2} + \frac{V[p_t]}{p_t^2}\right] \qquad (8)$$

Contribution estimates were produced not only for the same year but also for successive years to investigate delayed contribution or potential bias in contributions over time.

RESULTS AND DISCUSSION

Abundance in Caribou Creek

Of 4,916 grayling captured, 3,967 fish were marked and released with tags between 1980 and 1987 in Caribou Creek (from Appendix B3). An additional 490 fish in 1983 were marked and released with finclips. From those fish marked and released, 368 were recaptured from 1981 through 1987 and used in the Robson-Flick model (Table 3). The model produced six abundance estimates from the eight years of Caribou Creek data. No estimate was generated for the 1984 population because the three recaptures prevented the culling of recruitment. Abundance estimates ranged from 9,820 grayling (SE = 2,058) in 1980 to 4,877 grayling (SE = 943) in 1986 with coefficients of variation ranging from 9.4% in 1983 to 21.6% in 1985 (Table 3). While differences in capture probability due to size selectivity were found to have occurred during the first event in four of the six estimates (Table 4, Appendices E1-E6) and implied a bias in the abundance estimates, the bias most likely resulted from variable recruitment between events and not gear selectivity. The second KS test between the two events, comparing the lengths of fish marked to those recaptured in the second event, found no differences in four of the six estimates and inferred that no bias was present in the second event. Since this second event was also the first event for the next abundance experiment, the case for a non-gear-selectivity related cause is strongly supported. Since the Robson-Flick model was developed to accommodate recruitment, the abundance estimates for 1980 through 1982 and for 1986 are considered unbiased.

The 1983 and 1985 estimates of abundance appear to be biased. The statistical differences in the KS test between marks and recaptures for the 1983 estimate and functional differences seen for the 1985 estimate (Table 4, Appendices E4 and E5) inferred that some bias was present in the estimates. For both data sets, there were less recaptures of smaller sized fish than expected. There was significant difference in the probability of capture between fish of lengths 270 through 329 mm and those ≥330 mm: for 1983, $p = 0.10$ and $p = 0.19$, respectively; $\chi^2 = 10.00$, df = 1, $p = 0.0016$; for 1985, $p = 0.04$ and $p = 0.21$, respectively; $\chi^2 = 9.02$, df = 1, $p = 0.0027$). The similarity and equal distance between the distribution curves for the 1984 (Appendix E4) data suggests that the growth adjustment applied to recaptured fish (see Methods) could be the cause of the bias. Holmes et al. (1986) reported that the 1985 sample was distinctly different in regards to total catch and tag recapture rates when compared to previous years (Appendix B4) and noted that grayling were observed in a normally marshy area of the drainage (in 1985 it was a navigable lake) 3.2 km below Caribou Creek. They suggested that persistent high water during sampling displaced grayling from Caribou Creek in 1985.

Table 3. Summary of statistics and parameter estimates from the Robson-Flick model for abundance estimation of Arctic grayling (^270 mm FL) in Caribou Creek, 1980 -1986.

						Robson-Flick statistics[a]									95% confidence interval[b]	
Year(i)	M(i)	C(i+1)[c]	R(i+1)	R/M[d]	R/C[d]	R'	length	r	r+1	u(r+1)	Sum	N(i)	SE	cv%	N(i)	_%
1980	900	641	19	0.02	0.03	18	312	7	8	9.9	688.9	9,820	2,058	21.0%	5,800 - 13,900	41%
1981	635	1,406	105	0.17	0.08	55	322	31	32	14.4	2,782.2	9,793	1,370	14.0%	7,100 - 12,500	27%
1982	1,387	779	132	0.10	0.17	83	321	34	35	3.7	564.9	6,495	666	10.3%	5,200 - 7,800	20%
1983	679	632	78	0.12	0.12	53	305	8	9	8.1	1,517.2	6,187	582	9.4%	5,000 - 7,300	18%
1984	308	192	3	0.01	0.02	ND[e]	---	---	---	---	---	---	---	---	---	---
1985	190	367	11	0.06	0.03	10	303	1	2	25.3	2,904.1	5,022	1,085	21.6%	2,900 - 7,100	42%
1986	363	343	20	0.06	0.06	16	327	6	7	12.4	738.5	4,877	943	19.3%	3,000 - 6,700	38%
Total			368													

[a] Statistics were generated for the Robson-Flick estimator from a spreadsheet program associated with Bernard and Hansen (1992) and are: R' = the number of recaptures of marked fish (cells) with unique lengths in the second event; length = the estimated length at which recruitment is negligible (corresponding to cell r+1); r = the last cell (length group) significantly influenced by recruitment; u(r+1) = the running average of unmarked fish in cell r+1; and, Sum = the sum of counts of unmarked fish in cell *i* minus the running average of unmarked fish in cell *i*+1.

[b] Confidence intervals calculated as N ± *t* * SE (a = 0.05, df = $) and rounded to nearest hundred fish.

[c] C and R are from year *i*+1. M is from year *i*.

[d] R/M is the rate of the number of recaptures of marked fish to the total number of marked fish released in the first (mark) event. R/C is the rate of the number of recaptures of marked fish to the total catch of fish in the second (recapture) event.

[e] ND = not done. Lack of recaptures prevented detection of recruitment and application of estimator.

Table 4. Kolmogorov-Smirnov test statistics from capture-recapture data[a] of Arctic grayling (≥270 mm FL) in Caribou Creek used in the Robson-Flick model, 1980 - 1987.

Years of sampling	Marks vs Unmarked		Marks vs Recaptures	
	D	p	D	p
1980-1981	0.35	0.00	0.20	0.47
1981-1982	0.21	0.00	0.07	0.82
1982-1983	0.06	0.08	0.14	0.02
1983-1984	0.28	0.00	0.22	<0.01
1984-1985	ND[b]	---	ND	---
1985-1986	0.35	0.00	0.33	0.22
1986-1987	0.07	0.42	0.14	0.84

[a] Tests compared the lengths of fish marked in year *i* to lengths (at time of marking) of marked fish recaptured in year *i*+1 and to lengths of unmarked fish captured in year *i*+1. Tests are plotted as cumulative function distributions in Appendix E.

[b] ND = not done.

Contribution Rate

The proportion of marked grayling released in Caribou Creek ranged from 0.03 (SE = <0.01) in 1983 to 0.21 (SE = 0.02) in 1982 (Table 5).

Caribou Creek to Richardson Clearwater River:

The proportion of marked grayling from Caribou Creek sampled at the Richardson Clearwater River in the same year (p_m) ranged from 0.01 for the 1985 release to 0.12 for the 1982 release (Appendix C2). Using abundances estimated with the Robson-Flick model, contribution of grayling released in Caribou Creek that migrated to the Richardson Clearwater River in the same year ranged from 1.03 (SE = 0.35; or 103%) in 1980 to 0.32 (SE = 0.18; or 32%) in 1985, with an average of 0.67 (SE = 0.11; or 67%, Table 6). Average contribution decreased in following years (Table 6).

These results imply that, on average, two-thirds of the population in the Richardson Clearwater River is comprised of fish that emigrated from Caribou Creek the same year. The remaining one-third of the population could be comprised of fish from other tributaries of the Shaw Creek drainage, or from other donor streams, or a combination of donors.

Caribou Creek to Tanana River at Shaw Creek:

The proportion of marked grayling from Caribou Creek sampled at the Tanana River near Shaw Creek one year later (p_m), ranged from 0.01 for the 1984 and 1985 releases to 0.09 for the 1983 release (Appendix A3). Using abundances estimated with the Robson-Flick model, contribution of grayling released in Caribou Creek that migrated to the mouth of Shaw Creek one year later ranged from 0.75 (SE = 0.24) in 1986 to 0.17 (SE = 0.17) in 1985, with an average of 0.48 (SE = 0.07; Table 7). Average contribution decreased in following years (Table 7).

These results imply that, on average, one-half of the population at the mouth of Shaw Creek during the pre-spawning migration is comprised of fish that originated from Caribou Creek the prior year. The remaining one-half could be comprised of new recruits to Caribou Creek, fish from other tributaries to Shaw Creek, fish from other systems, or a combination of all of these potential donors.

Caribou Creek to Caribou Creek:

The proportion of marked grayling from Caribou Creek sampled at Caribou Creek one year later (p_m) ranged from 0.02 for the 1985 release to 0.17 for the 1983 release (Appendix B4). Using abundances estimated with the Robson-Flick model, contribution of grayling released in Caribou Creek that came back to Caribou Creek one year later ranged from 1.15 (SE = 0.19) in 1981 to 0.32 (SE = 0.10) in 1980, with an average of 0.73 (SE = 0.08; Table 8). Average contribution decreased in following years (Table 8).

These results imply that, on average, three-quarters of the population in Caribou Creek during the post-spawning migration is comprised of fish that originated from Caribou Creek the prior year. The remaining one-quarter

Table 5. Estimates of the proportion of Arctic grayling (≥270 mm FL) marked in Caribou Creek, 1980 - 1986 based on Robson-Flick estimates of abundance.

Year	m_t[a]	N_t[b]	SE[c]	p_t[d]	SE[e]
1980	899	9,820	2,058	0.09	0.02
1981	635	9,793	1,370	0.07	0.01
1982	1,387	6,495	666	0.21	0.02
1983	186	6,187	582	0.03	<0.01
1984	ND	---	---	---	---
1985	190	5,022	1,085	0.04	0.01
1986	363	4,877	943	0.07	0.01

[a] m_t = the number of Arctic grayling released with marks in year t.
[b] N_t = the estimated abundance of Arctic grayling in year t.
[c] SE = the standard error of the estimated abundance in year t.
[d] p_t = the proportion of Arctic grayling with marks in year t.
[e] SE = the standard error of p_t.

Table 6. Estimates of the contribution (p_c) and standard error of Arctic grayling (≥270 mm FL) marked and released in year *i* in Caribou Creek and recovered in the Richardson Clearwater River, 1980 - 1988. Contributions are based on the Robson-Flick model of abundance estimation in Caribou Creek.

Year (*i*) of release	Year of recapture in the Richardson Clearwater River							
	i	*i*+1	*i*+2	*i*+3	*i*+4	*i*+5	*i*+6	*i*+7
1980	1.03	0.53	0.86	0.37	0.16	0.27	0	0.03
SE	0.35	0.22	0.26	0.17	0.10	0.11	---	0.03
1981	0.64	0.52	0.61	0.07	0.05	0	0	0.04
SE	0.27	0.19	0.24	0.07	0.05	---	---	0.03
1982	0.55	0.34	0.23	0.16	0.07	0.04	0.03	
SE	0.11	0.10	0.07	0.05	0.04	0.02	0.01	
1983	0.94	0.48	0.31	0.32	0	0.14		
SE	0.42	0.28	0.18	0.23	---	0.08		
1984	NE[a]	---	---	---	---			
SE	---	---	---	---	---			
1985	0.32	0.13	0.06	0.18				
SE	0.18	0.13	0.06	0.09				
1986	0.52	0.29	0.20					
SE	0.21	0.11	0.07					
Average	0.67	0.38	0.38	0.22	0.07	0.11	0.01	0.03
SE	0.11	0.07	0.07	0.06	0.03	0.03	<0.01	0.02

[a] NE = no estimate.

Table 7. Estimates of the contribution (p_c) and standard error of Arctic grayling (≥270 mm FL) marked and released in year *i* in Caribou Creek and recovered in the Tanana River at the mouth of Shaw Creek, 1980 - 1988. Contributions are based on the Robson-Flick model of abundance estimation in Caribou Creek.

Year (*i*) of release	Year of recapture at the mouth of Shaw Creek						
	i+1	*i*+2	*i*+3	*i*+4	*i*+5	*i*+6	*i*+7
1980	0.55	0.52	0.27	0.09	0.09	0.07	0.17
SE	0.17	0.17	0.12	0.06	0.06	0.07	0.09
1981	0.69	0.33	0.13	0.04	0	0.18	0
SE	0.20	0.14	0.08	0.04	---	0.11	---
1982	0.42	0.15	0.10	0.03	0.11	0	
SE	0.09	0.04	0.05	0.03	0.05	---	
1983	0.28	0.28	0	0.13	0		
SE	0.17	0.16	---	0.13	---		
1984	NE[a]	---	---	---			
SE	---	---	---	---			
1985	0.17	0.53	0.37				
SE	0.17	0.26	0.22				
1986	0.75	0.50					
SE	0.24	0.20					
Average	0.48	0.38	0.17	0.07	0.05	0.08	0.09
SE	0.07	0.07	0.05	0.04	0.02	0.04	0.05

[a] NE = no estimate.

Table 8. Estimates of the contribution (p_c) and standard error of Arctic grayling (≥270 mm FL) marked and released in year *i* in Caribou Creek and recovered in Caribou Creek, 1980 - 1987. Contributions are based on the Robson-Flick model of abundance estimation in Caribou Creek.

Year (*i*) of release	Year of recapture in Caribou Creek						
	i+1	*i*+2	*i*+3	*i*+4	*i*+5	*i*+6	*i*+7
1980	0.32	0.50	0.31	0.48	0.11	0.12	0.06
SE	0.10	0.12	0.09	0.14	0.08	0.06	0.05
1981	1.15	0.87	0.46	0	0.08	0.04	
SE	0.19	0.18	0.12	---	0.06	0.05	
1982	0.79	0.56	0.02	0.13	0.15		
SE	0.10	0.08	0.02	0.04	0.05		
1983	1.00	0.17	0.54	0.68			
SE	0.24	0.17	0.23	0.26			
1984	NE[a]	---	---				
SE	---	---	---				
1985	0.79	0.85					
SE	0.29	0.31					
1986	0.35						
SE	0.13						
Average	0.73	0.59	0.33	0.32	0.11	0.08	0.06
SE	0.08	0.08	0.07	0.10	0.04	0.04	0.05

[a] NE = no estimate.

should be comprised of new recruits to Caribou Creek if homing to natal streams for spawning was occurring.

CONCLUSIONS

1. A majority of grayling (≥ 270 mm FL) in the Richardson Clearwater River are from the Caribou Creek population. Management of these two systems must be linked.

2. A majority of grayling (≥ 270 mm FL) potentially harvestable in the spring fishery at Shaw Creek are from Caribou Creek. Management of this fishery must take into account exploitation in the Richardson Clearwater River.

3. Homing to the spawning area at Caribou Creek is indicated. Declines in abundance at Caribou Creek can be minimally attributed to exploitation in the Richardson Clearwater River and any future spring fishery at Shaw Creek.

RECOMMENDATIONS

1. Identify donor stocks and streams to the Richardson Clearwater River for the unexplained 33% of contributions. Potential candidates for research are the Goodpaster River, Salcha River, and Volkmar River.

2. Develop a management plan for the Caribou Creek stock that addresses utilization of these fish in the Richardson Clearwater River fishery and any future fishery at Shaw Creek.

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APPENDIX A

Appendix A1. Summary of Arctic grayling sampled[a] during early spring at the mouth of Shaw Creek, 1981 - 1988.

Year	Dates	Total	>269mm FL			>329mm FL		
			n	p[b]	SE[c]	n	p[d]	SE
1981	5 - 22 April	471	357	0.76	0.02	82	0.23	0.02
1982	24 April - 2 May	384	314	0.82	0.02	92	0.29	0.03
1983	17 - 24 April	305	279	0.92	0.02	144	0.52	0.03
1984	8 - 25 April	364	351	0.96	0.01	141	0.40	0.03
1985	27 - 30 April	402	360	0.90	0.02	101	0.28	0.02
1986	24 April - 4 May	184	156	0.85	0.03	49	0.31	0.04
1987	15 - 23 April	267	251	0.94	0.02	192	0.77	0.03
1988	18 - 22 April	338	214	0.63	0.03	101	0.47	0.03
Total		2,715	2,282	0.84	0.01	902	0.40	0.01

[a] Samples came from angler creels in 1981 through 1986 and from electrofishing in 1987 and 1988.

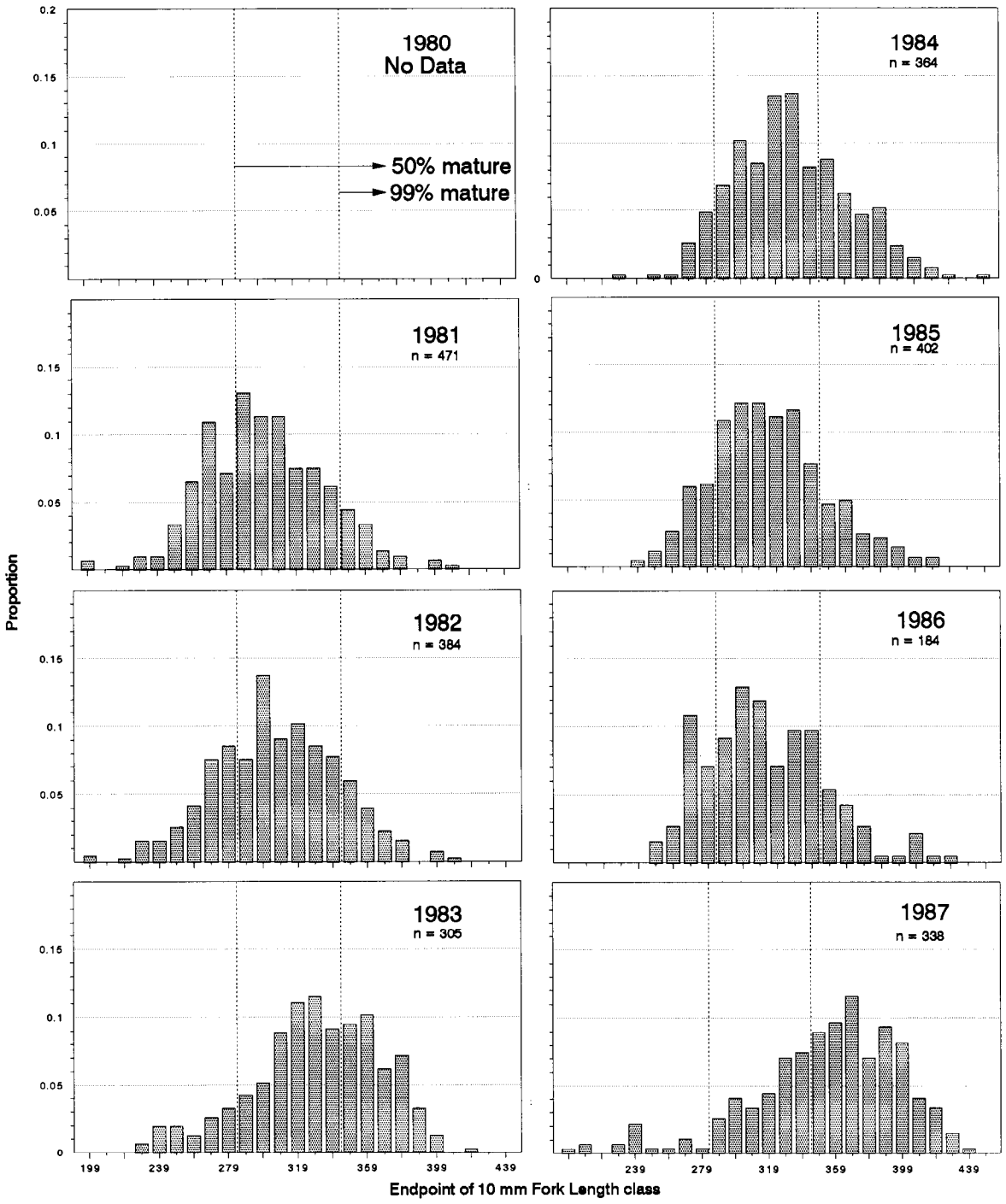
[b] p = proportion of total catch.

[c] SE = standard error of the proportion.

[d] p = proportion of catch greater than 269 mm FL that were greater than 329 mm FL.

Appendix A2.1. The number of Arctic grayling in 10 mm FL groups in samples from the Tanana River at the mouth of Shaw Creek from angler creels, April, 1981 - 1986, and from electrofishing, April, 1987 and 1988.

Length	1981	1982	1983	1984	1985	1986	1987	1988
<270	70	70	26	13	42	28	16	124
270 - 279	21	33	10	18	25	13	1	18
280 - 289	38	29	13	25	44	17	7	22
290 - 299	33	53	16	37	49	24	11	18
300 - 309	33	35	27	31	49	22	9	22
310 - 319	22	39	34	49	45	13	12	18
320 - 329	22	33	35	50	47	18	19	15
330 - 339	18	30	28	30	31	18	20	20
340 - 349	13	23	29	32	19	10	24	21
350 - 359	10	17	31	23	20	8	26	14
360 - 369	4	9	19	17	10	5	31	14
370 - 379	3	6	22	19	9	1	19	11
380 - 389	0	3	10	9	6	1	25	8
390 - 399	2	3	4	6	3	4	22	3
400 - 409	1	1	0	3	3	1	11	7
410 - 419	0	0	1	1	0	1	9	1
420 - 429	0	0	0	0	0	0	4	1
430 - 439	0	0	0	0	0	0	1	1
440 - 449	0	0	0	1	0	0	0	0
Totals	290	384	305	364	402	184	267	338



Appendix A2.2. Yearly length frequencies of Arctic grayling sampled in April at the mouth of Shaw Creek 1981 through 1988.

Appendix A3. Number (R) and recapture rates (p_m[a]) of Arctic grayling (^270 mm FL) that were tagged and released in Caribou Creek and recaptured from the Tanana River at the mouth of Shaw Creek, 1981 through 1988.

Tagging Year:		1980			1981			1982			1983			1984		
Year[b]	n[c]	R	p_m	SE	R	p_m	SE	R	p_m	SE	R	p_m	SE	R	p_m	SE
1981	357	18	0.05	0.01	---	---	---	---	---	---	---	---	---	---	---	---
1982	314	15	0.05	0.01	14	0.04	0.01	---	---	---	---	---	---	---	---	---
1983	279	7	0.03	0.01	6	0.02	0.01	25	0.09	0.02	---	---	---	---	---	---
1984	351	3	0.01	<0.01	3	0.01	<0.01	11	0.03	0.01	3	0.01	<0.01	---	---	---
1985	360	3	0.01	<0.01	1	<0.01	<0.01	8	0.02	0.01	3	0.01	<0.01	9	0.03	0.01
1986	156	1	0.01	0.01	0	0	---	1	0.01	0.01	0	0	---	2	0.01	0.01
1987	251	4	0.02	0.01	3	0.01	0.01	6	0.02	0.01	1	<0.01	<0.01	4	0.02	0.01
1988	217	0	0	---	0	0	---	0	0	---	0	0	---	2	0.01	0.01

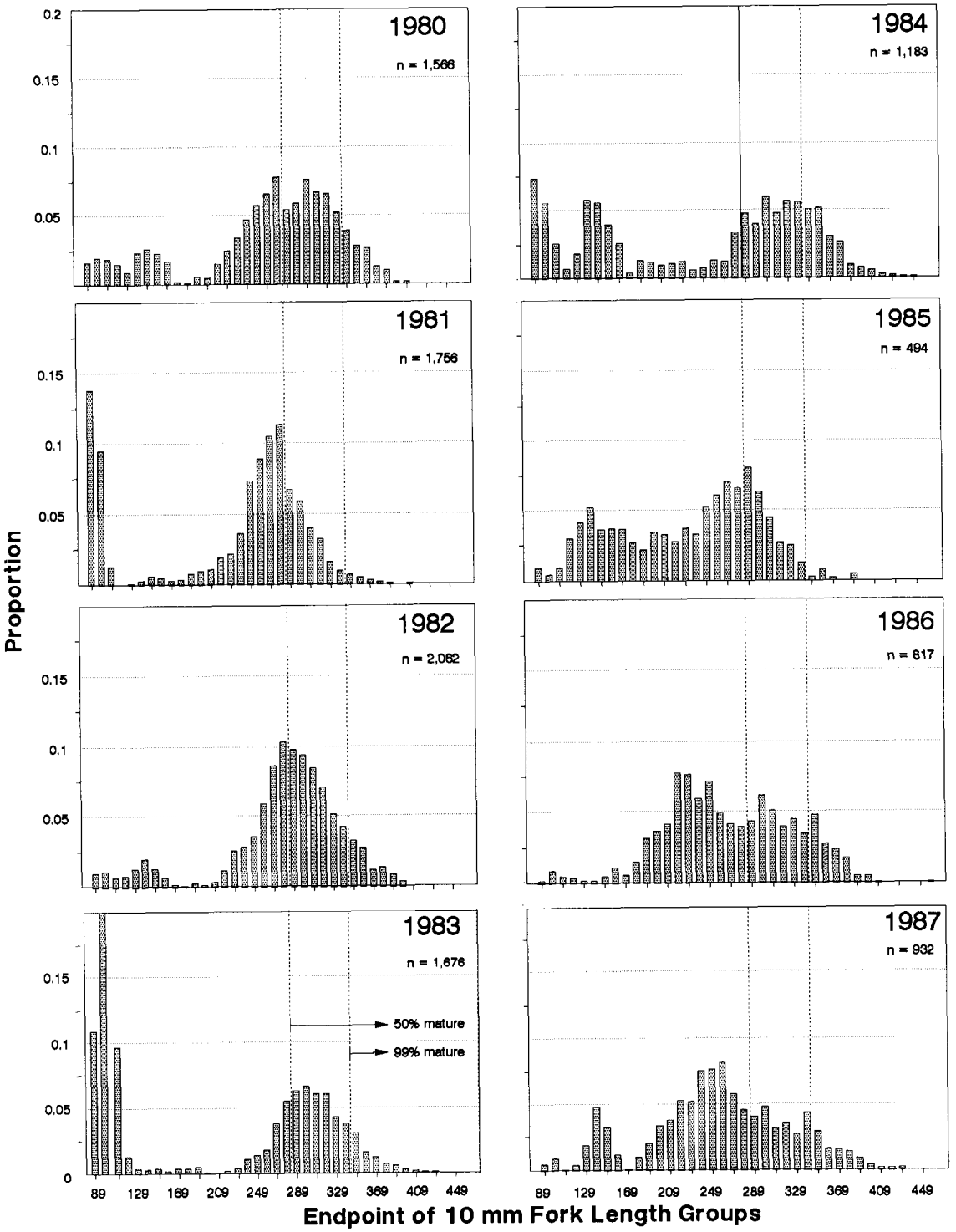
Tagging Year:		1985			1986			1987		
Year	n	R	p_m	SE	R	p_m	SE	R	p_m	SE
1981	357	---	---	---	---	---	---	---	---	---
1982	314	---	---	---	---	---	---	---	---	---
1983	279	---	---	---	---	---	---	---	---	---
1984	351	---	---	---	---	---	---	---	---	---
1985	360	---	---	---	---	---	---	---	---	---
1986	156	1	0.01	0.01	---	---	---	---	---	---
1987	251	5	0.02	0.01	14	0.06	0.01	---	---	---
1988	217	3	0.01	0.01	8	0.04	0.01	7	0.03	0.01

[a] p_m = recapture rate; recaptures/sample size.
[b] Year = sample year.
[c] n = sample size.

APPENDIX B

Appendix B1.1 The number of Arctic grayling in 10 mm FL groups in samples from Caribou Creek, June, 1980 - 1987.

Length	1980	1981	1982	1983	1984	1985	1986	1987
<270	667	1,483	2,470	897	551	302	450	589
270 - 279	123	206	237	93	40	37	32	43
280 - 289	84	123	217	106	57	45	36	38
290 - 299	94	101	205	112	47	36	51	45
300 - 309	119	71	189	103	71	24	43	29
310 - 319	106	59	149	102	57	16	34	34
320 - 329	103	28	112	72	68	15	37	26
330 - 339	82	18	89	64	66	8	29	41
340 - 349	61	13	68	51	60	2	38	27
350 - 359	44	9	59	26	61	5	23	15
360 - 369	42	6	25	20	37	1	19	14
370 - 379	21	3	28	11	32	0	15	13
380 - 389	15	2	18	10	12	3	4	8
390 - 399	3	0	9	4	10	0	4	4
400 - 409	3	1	1	3	7	0	1	2
410 - 419	0	0	0	1	3	0	0	2
420 - 429	0	0	0	1	2	0	0	2
430 - 439	0	0	0	0	2	0	0	0
440 - 449	0	0	0	0	0	0	1	0
Totals	1,567	2,123	3,876	1,676	1,183	494	817	932



Appendix B1.2. Yearly length frequencies of Arctic grayling sampled during the June outmigration from Caribou Creek, 1980 - 1987.

Appendix B2. Summary statistics and test results for comparisons between recaptures of Arctic grayling (≥270 mm FL) tagged in Caribou Creek in 1981 - 1983 and finclipped in 1983.

Year	Event	Sample Size	Mean Length	STD	Min	Max	Mean Growth	Testing[a] D[b]	Testing[a] p[b]	Testing[a] t[c]	Testing[a] p[c]
1981	Mark	105	295	23	270	369					
1982	Recapture	105	313	23	280	385	18	0.35	<0.01	-4.101	<0.01
1982	Mark	132	312	29	270	392					
1983	Recapture	132	327	29	273	403	15	0.11	0.73	-0.477	0.63
1983	Mark	19	334	32	287	396					
1984	Recapture	19	347	31	288	396	13	0.31	0.14	2.466	0.02
1983[d]	Recapture in 1984	59	329	26	285	399					

[a] Testing was between 1983 finclipped recaptures and the tag recaptures.

[b] Kolmogorov-Smirnov two sample test statistic and probability.

[c] A t-test for the null hypothesis concerning the difference between the mean length of finclipped recaptures versus the mean length of tagged recaptures.

[d] Finclipped recaptures.

Appendix B3. Summary of captures and marks released[a] of Arctic grayling during spring sampling, Caribou Creek, 1980 - 1987.

Year	Dates	Effort (Days)	Migrant[b]	Catch							Marks (>269) Released			
				Total	Catch >269mm FL			Catch >329mm FL			Total	Marks >329mm FL		
					n	p[c]	SE[d]	n	p[e]	SE		n	p[e]	SE
1980	18 May - 12 June	25	US+DS	1,567	900	0.57	0.01	271	0.30	0.02	899	271	0.30	0.02
1981	6 June - 19 June	13	US+DS	2,123	640	0.30	0.01	52	0.08	0.01	635	52	0.08	0.01
1982	1 June - 20 June	19	US+DS	3,876	1,406	0.36	0.01	297	0.21	0.01	1,387	293	0.21	0.01
1983	2 June - 20 June	16[f]	DS	1,676	779	0.47	0.01	191	0.25	0.02	186	142	0.76	0.03
1984	4 June - 15 June	11	DS	1,183	632	0.53	0.02	292	0.46	0.02	308	165	0.54	0.03
1985	4 June - 15 June	11	DS	494	192	0.39	0.02	19	0.10	0.02	190	19	0.10	0.02
1986	2 June - 18 June	16	DS	817	367	0.45	0.02	136	0.37	0.03	363	134	0.37	0.03
1987	3 June - 11 June	8	DS	932	343	0.37	0.02	128	0.37	0.03	341	128	0.38	0.03
Total				12,668	5,259	0.42	0.00	1,386	0.26	0.01	4,308	1,204	0.28	0.01

[a] Marks were anchor tags.
[b] Catch represents fish migrating US (upstream) and/or DS (downstream).
[c] p = proportion of total catch that were >269 mm FL.
[d] SE = standard error of the proportion.
[e] p = proportion of catch greater than 269 mm FL that were >329 mm FL.
[f] Weir was closed for two days, 6 - 8 June.

Appendix B4. Number (R) and recapture rates (p_m[a]) of Arctic grayling (^270 mm FL) that were tagged and released in Caribou Creek and recaptured in Caribou Creek, 1980 - 1987.

Tagging Year:		1980			1981			1982			1983			1984		
Year[b]	n[c]	R	p_m	SE	R	p_m	SE	R	p_m	SE	R	p_m	SE	R	p_m	SE
1980	900	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
1981	641	19	0.03	0.01	---	---	---	---	---	---	---	---	---	---	---	---
1982	1,406	65	0.05	0.01	105	0.07	0.01	---	---	---	---	---	---	---	---	---
1983	779	22	0.03	0.01	44	0.06	0.01	132	0.17	0.01	---	---	---	---	---	---
1984	632	28	0.04	0.01	19	0.03	0.01	75	0.12	0.01	19	0.03	0.01	---	---	---
1985	192	2	0.01	0.01	0	0	---	1	0.01	0.01	1	0.01	0.01	3	0.02	0.01
1986	367	4	0.01	0.01	2	0.01	<0.01	10	0.03	0.01	6	0.02	0.01	6	0.02	0.01
1987	343	2	0.01	<0.01	1	<0.01	<0.01	11	0.03	0.01	7	0.02	0.01	7	0.02	0.01

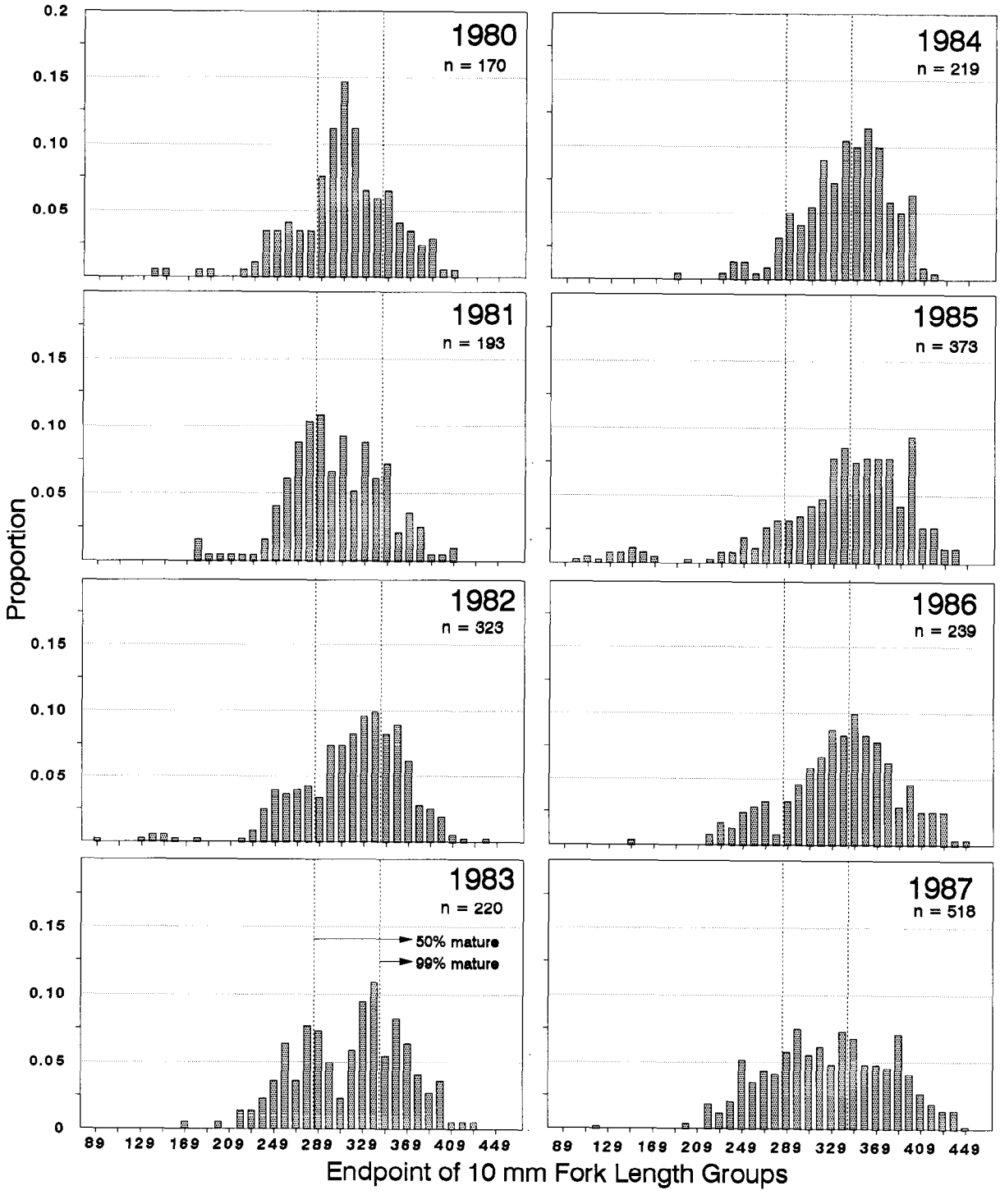
Tagging Year:		1985			1986		
Year	n	R	p_m	SE	R	p_m	SE
1980	900	---	---	---	---	---	---
1981	641	---	---	---	---	---	---
1982	1,406	---	---	---	---	---	---
1983	779	---	---	---	---	---	---
1984	632	---	---	---	---	---	---
1985	192	---	---	---	---	---	---
1986	367	11	0.03	0.01	---	---	---
1987	343	11	0.03	0.01	9	0.03	0.01

[a] p_m = recapture rate; recaptures/sample size.
[b] Year = sample year.
[c] n = sample size.

APPENDIX C

Appendix C1.1. The number of Arctic grayling in 10 mm FL groups captured by electrofishing, Richardson Clearwater River, July 1980 - 1988.

Length	1980	1981	1982	1983	1984	1985	1986	1987	1988
<270	32	48	57	43	11	47	31	98	126
270 - 279	6	20	14	17	7	12	2	21	53
280 - 289	13	21	11	16	11	12	8	30	59
290 - 299	19	13	24	11	9	13	11	39	62
300 - 309	25	18	24	5	12	16	14	29	65
310 - 319	19	10	27	13	20	18	16	32	60
320 - 329	11	17	31	21	16	29	21	25	49
330 - 339	10	12	32	24	23	32	20	38	45
340 - 349	11	14	27	12	22	28	24	35	61
350 - 359	7	4	29	18	25	29	20	25	47
360 - 369	6	7	20	14	22	29	19	25	50
370 - 379	4	5	9	9	13	29	15	24	48
380 - 389	5	1	8	6	11	16	7	37	40
390 - 399	1	1	6	8	14	35	11	21	31
400 - 409	1	2	2	1	2	10	6	14	27
410 - 419	0	0	1	1	1	10	6	10	18
420 - 429	0	0	0	1	0	4	6	7	10
430 - 439	0	0	1	0	0	4	1	7	4
440 - 449	0	0	0	0	0	0	1	1	5
Totals	170	193	323	220	219	373	239	518	860



Appendix C1.2. Yearly length frequencies of Arctic grayling sampled in July in the Richardson Clearwater River, 1980 - 1988.

Appendix C2. Number (R) and recapture rates (p_m[a]) of Arctic grayling (^270 mm FL) that were tagged and released in Caribou Creek and recaptured from Richardson Clearwater River, 1980 through 1988.

Tagging Year:		1980			1981			1982			1983			1984		
Year[b]	n[c]	R	p_m	SE	R	p_m	SE	R	p_m	SE	R	p_m	SE	R	p_m	SE
1980	138	13	0.09	0.03	---	---	---	---	---	---	---	---	---	---	---	---
1981	145	7	0.05	0.02	6	0.04	0.02	---	---	---	---	---	---	---	---	---
1982	266	21	0.08	0.02	9	0.03	0.01	31	0.12	0.02	---	---	---	---	---	---
1983	177	6	0.03	0.01	7	0.04	0.02	13	0.07	0.02	5	0.03	0.01	---	---	---
1984	208	3	0.01	0.01	1	0.01	0.01	10	0.05	0.01	3	0.01	0.01	12	0.06	0.02
1985	326	8	0.03	0.01	1	<0.01	<0.01	11	0.03	0.01	3	0.01	0.01	14	0.04	0.01
1986	208	0	0	---	0	0	---	3	0.01	0.01	2	0.01	0.01	2	0.01	0.01
1987	420	1	<0.01	<0.01	0	0	---	4	0.01	<0.01	0	0	---	6	0.01	0.01
1988	734	0	0	---	2	<0.01	<0.01	5	0.01	<0.01	3	<0.01	<0.01	7	0.01	<0.01

Tagging Year:		1985			1986			1987		
Year	n	R	p_m	SE	R	p_m	SE	R	p_m	SE
1980	138	---	---	---	---	---	---	---	---	---
1981	145	---	---	---	---	---	---	---	---	---
1982	266	---	---	---	---	---	---	---	---	---
1983	177	---	---	---	---	---	---	---	---	---
1984	208	---	---	---	---	---	---	---	---	---
1985	326	4	0.01	0.01	---	---	---	---	---	---
1986	208	1	<0.01	<0.01	8	0.04	0.01	---	---	---
1987	420	1	<0.01	<0.01	9	0.02	0.01	16	0.04	0.01
1988	734	5	0.01	<0.01	11	0.02	<0.01	29	0.04	0.01

[a] p_m = recapture rate; recaptures/sample size.
[b] Year = sample year.
[c] n = sample size.

APPENDIX D

Appendix D1. Data files[1] used to estimate abundance of Arctic grayling (≥270 mm FL) spawning in Caribou Creek and their contribution to the pre- spawning population at the mouth of Shaw Creek and the summer feeding population in the Richardson Clearwater River, 1980 through 1988.

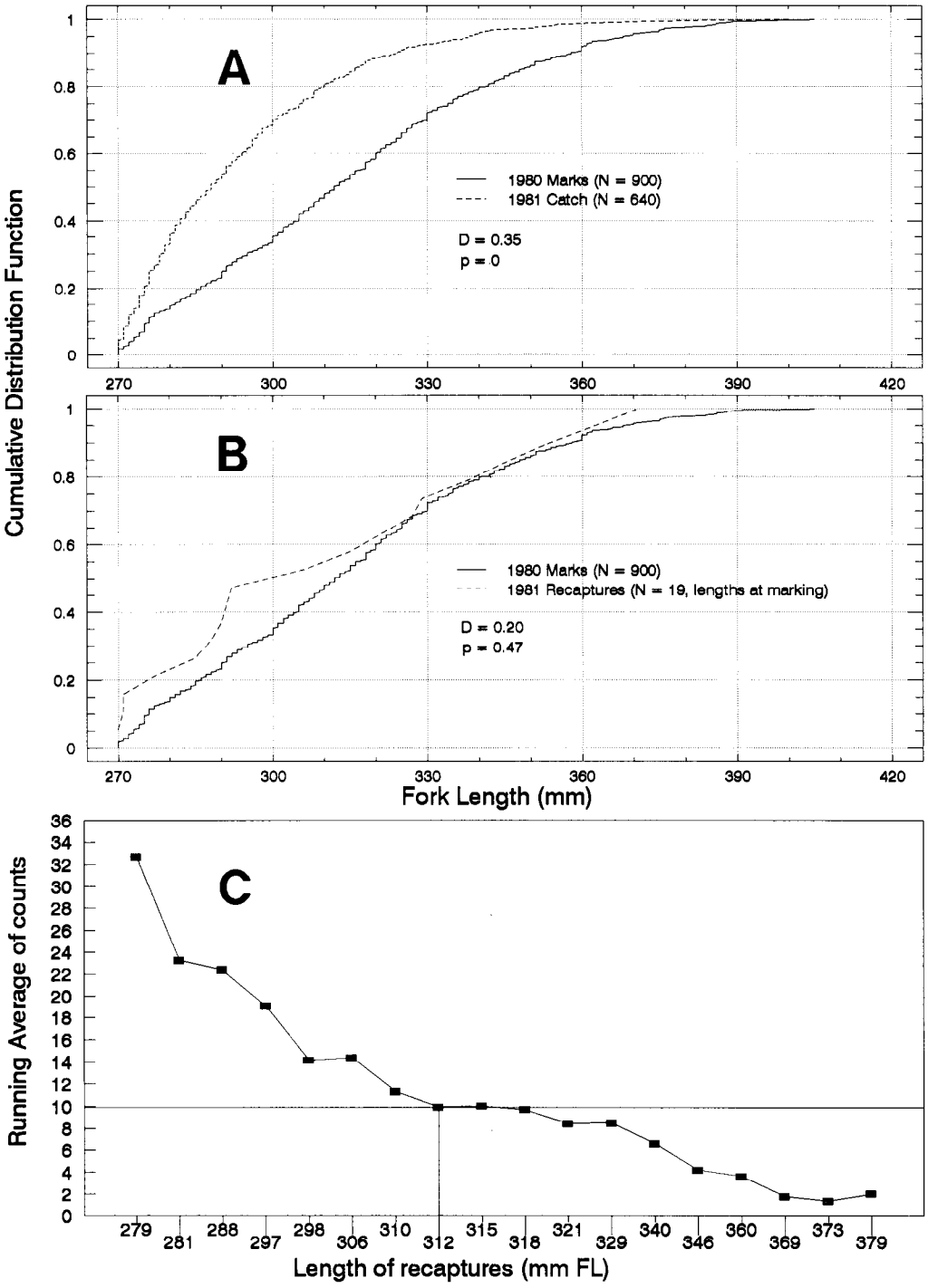
Data file	Description
U4810180.dta	All captures of Arctic grayling made in Caribou Creek in 1980.
U4810181.dta	All captures of Arctic grayling made in Caribou Creek in 1981.
U4810182.dta	All captures of Arctic grayling made in Caribou Creek in 1982.
U4810183.dta	All captures of Arctic grayling made in Caribou Creek in 1983.
U4810184.dta	All captures of Arctic grayling made in Caribou Creek in 1984.
U4810185.dta	All captures of Arctic grayling made in Caribou Creek in 1985.
U4810186.dta	All captures of Arctic grayling made in Caribou Creek in 1986.
U4810187.dta	All captures of Arctic grayling made in Caribou Creek in 1987.
U275PLA1.dta	1981 harvest sample of Arctic grayling from the April fishery in the Tanana River adjacent to the mouth of Shaw Creek.
U275PLA2.dta	1982 harvest sample of Arctic grayling from the April fishery in the Tanana River adjacent to the mouth of Shaw Creek.
U275PLA3.dta	1983 harvest sample of Arctic grayling from the April fishery in the Tanana River adjacent to the mouth of Shaw Creek.
U275PLA4.dta	1984 harvest sample of Arctic grayling from the April fishery in the Tanana River adjacent to the mouth of Shaw Creek.
U275PLA5.dta	1985 harvest sample of Arctic grayling from the April fishery in the Tanana River adjacent to the mouth of Shaw Creek.
U275PLA6.dta	1986 harvest sample of Arctic grayling from the April fishery in the Tanana River adjacent to the mouth of Shaw Creek.
U275PLA7.dta	All captures of Arctic grayling made in the Tanana River adjacent to the mouth of Shaw Creek in 1987.
U275PLA8.dta	All captures of Arctic grayling made in the Tanana River adjacent to the mouth of Shaw Creek in 1988.

- continued -

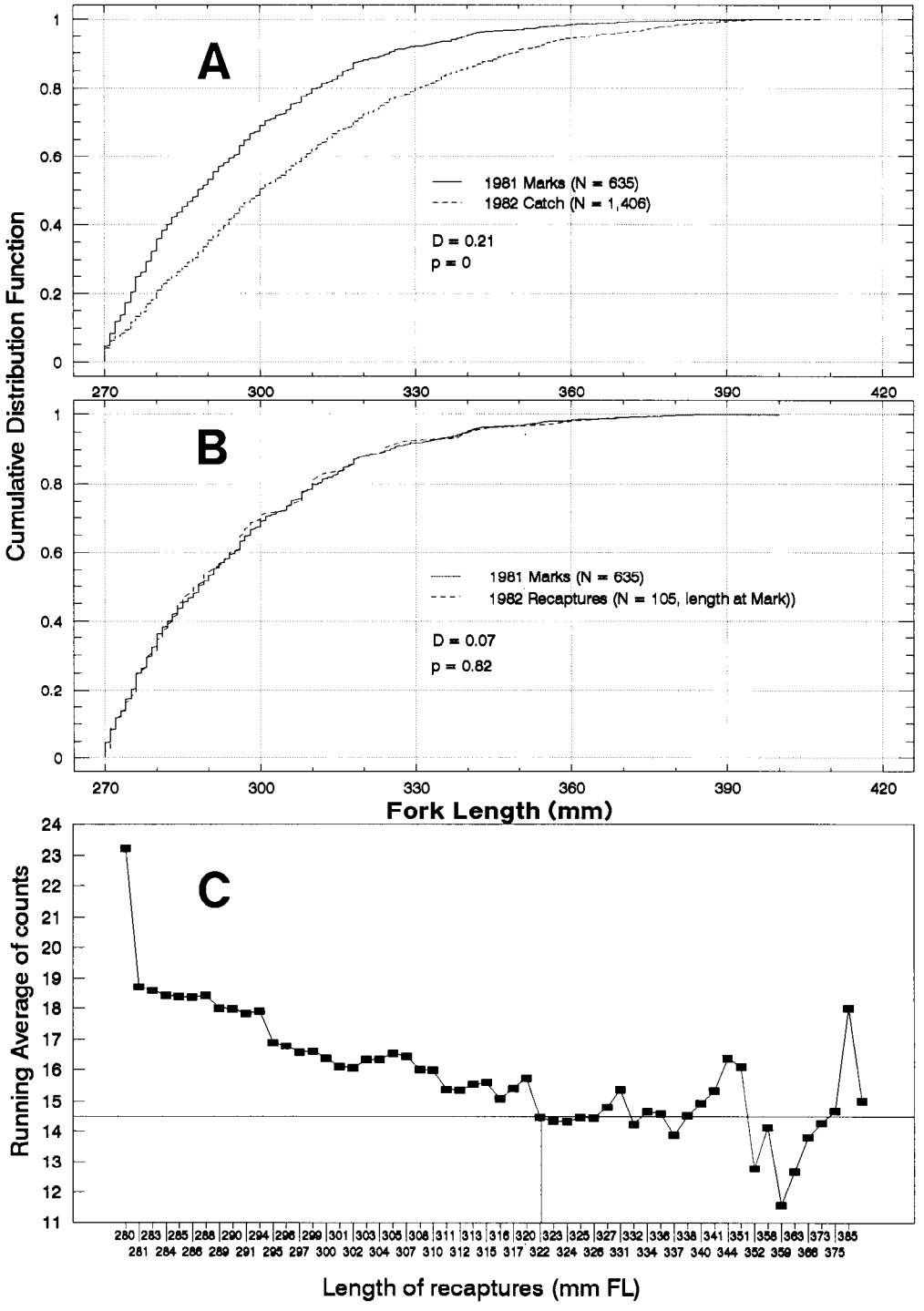
Data file	Description
U0070LB8.dta	All captures of Arctic grayling made in the Richardson Clearwater River in July 1980, 1981, and 1984.
U0070LD8.dta	All captures of Arctic grayling made in the Richardson Clearwater River in July 1982 and 1983.
U0070LA0.dta	All captures of Arctic grayling made in the Richardson Clearwater River in July 1985.
U0070LA6.dta	All captures of Arctic grayling made in the Richardson Clearwater River in July 1986.
U0070LA7.dta	All captures of Arctic grayling made in the Richardson Clearwater River in July 1987.
U0070LA8.dta	All captures of Arctic grayling made in the Richardson Clearwater River in July 1988.

[1] Data files have been archived at, and are available from the Alaska Department of Fish and Game, Sport Fish Division, Research and Technical Services, 333 Raspberry Road, Anchorage, Alaska 99518-1599. File names supersede those cited in Ridder 1991.

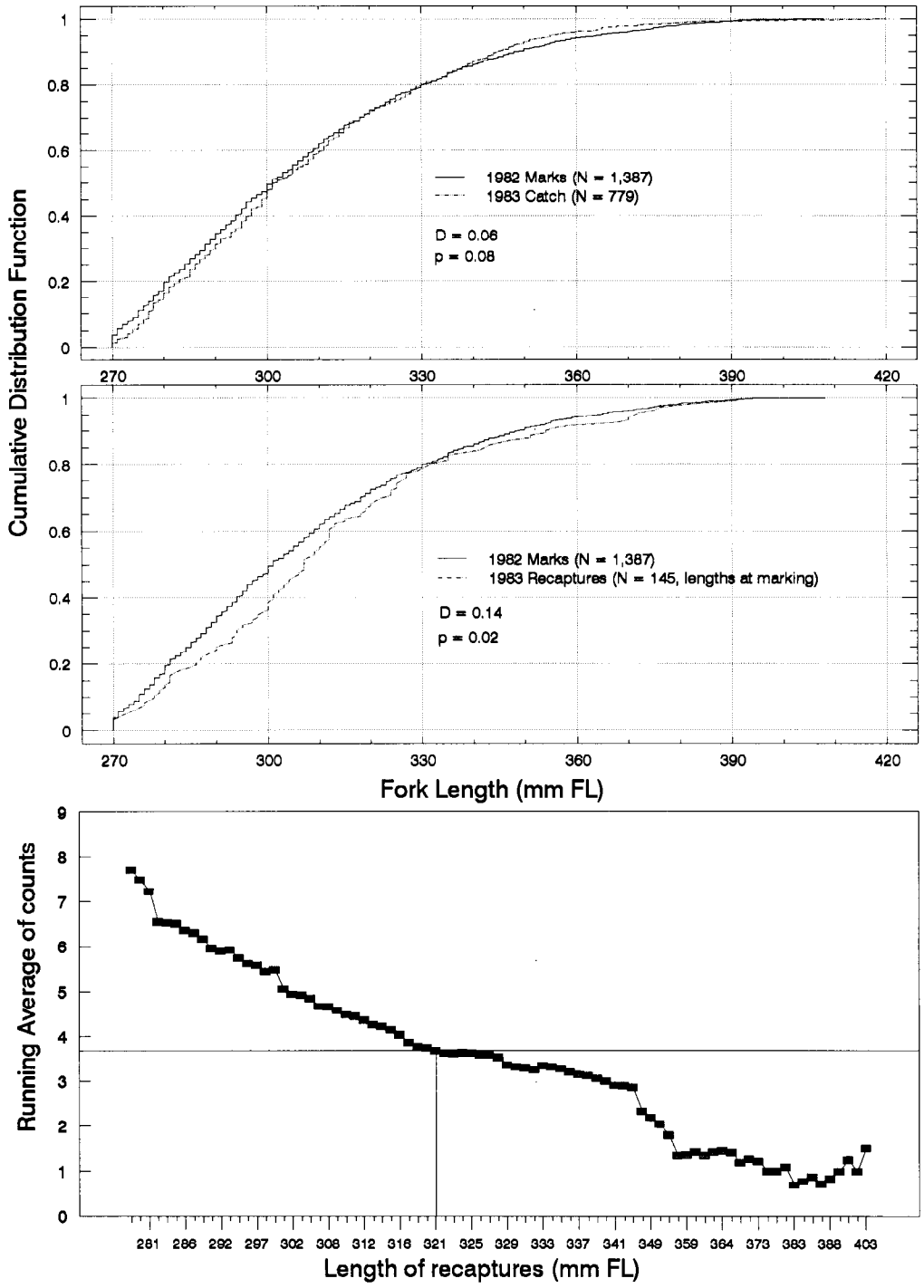
APPENDIX E



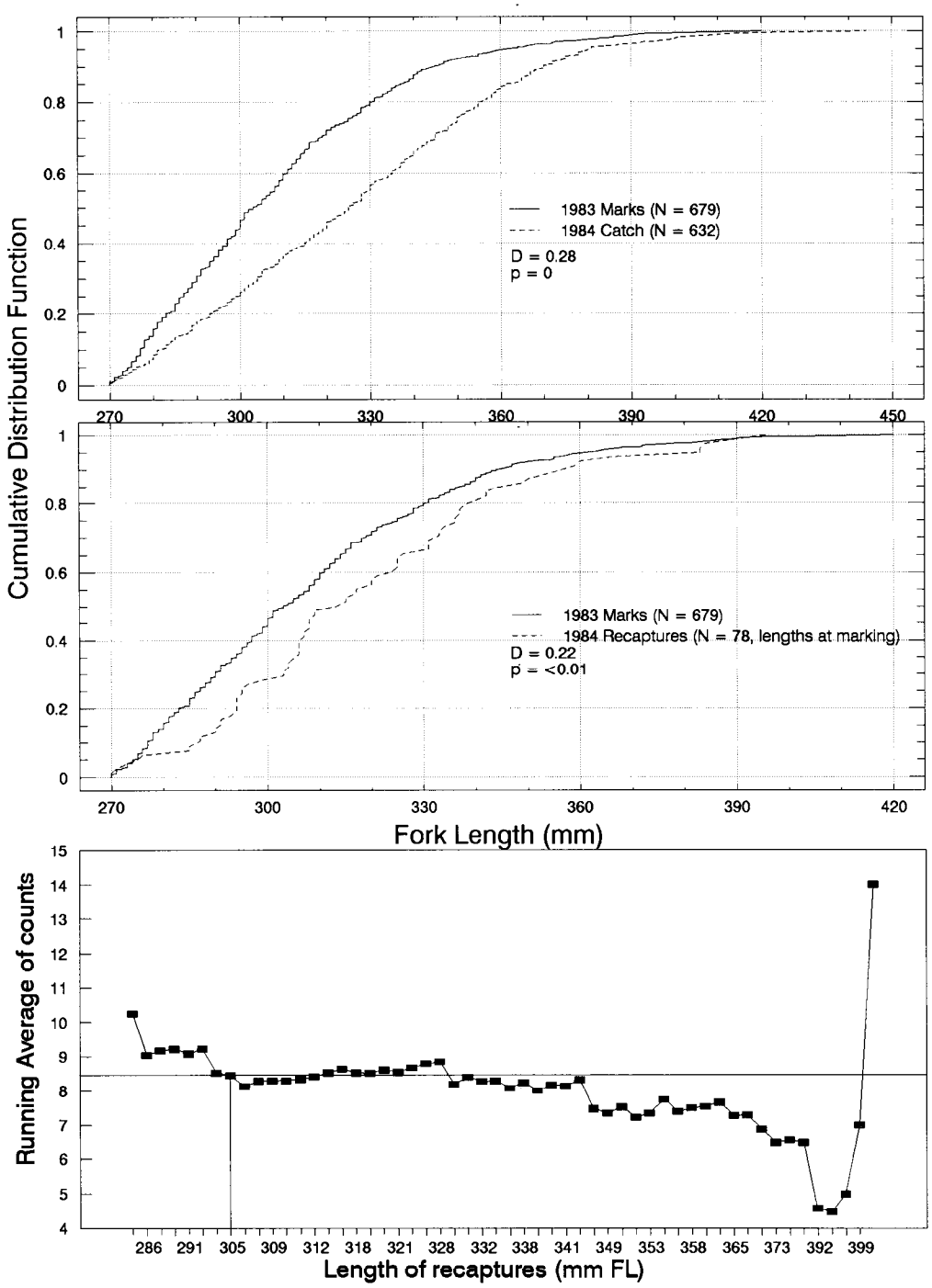
Appendix E1. Cumulative distribution functions of lengths of Arctic grayling marked versus those examined for marks (A) and versus those recaptured (B) and the Robson-Flick plot of average counts of unmarked Arctic grayling for each unique length of recaptured Arctic grayling (C) at Caribou Creek, 1980 and 1981.



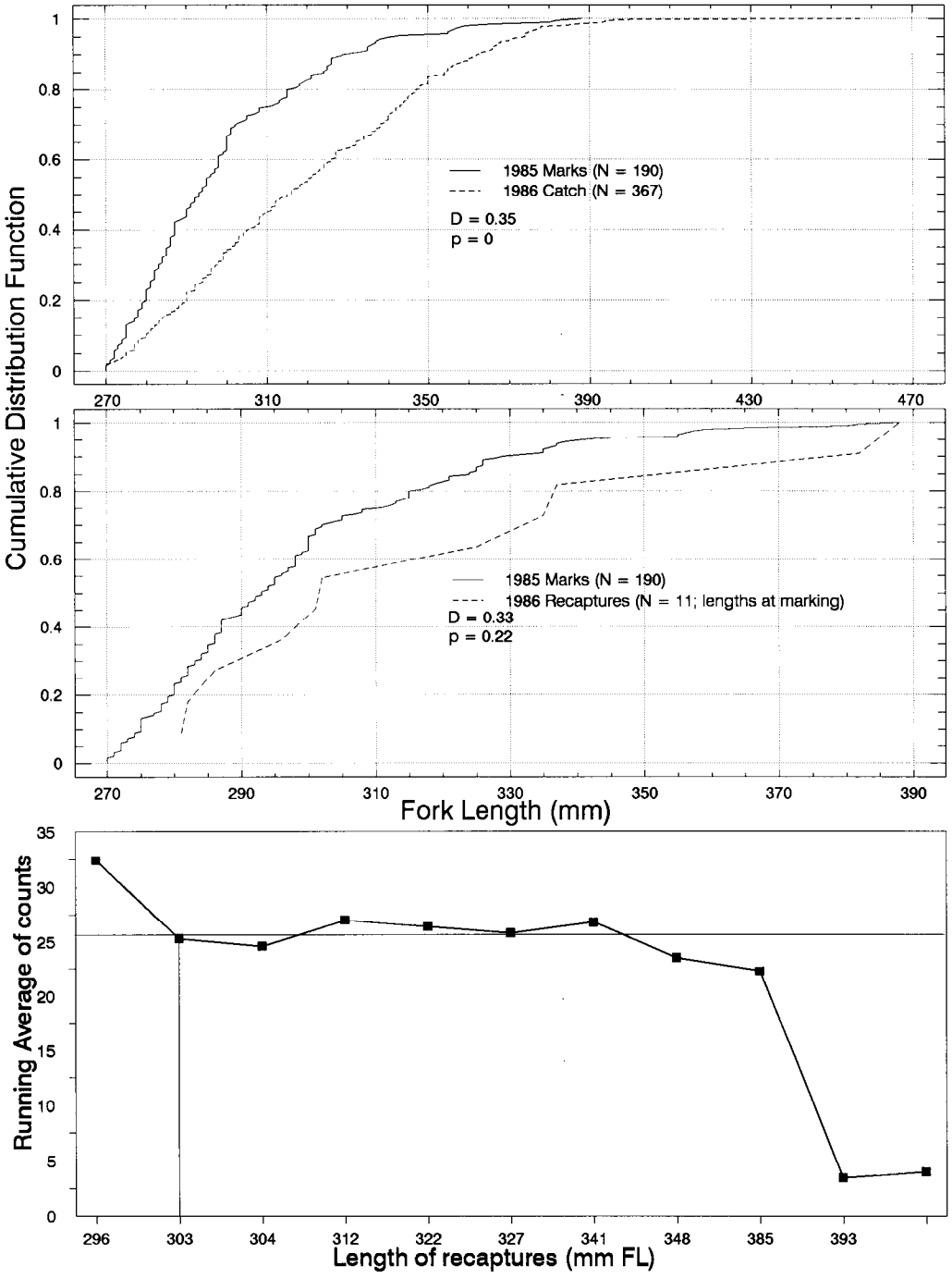
Appendix E2. Cumulative distribution functions of lengths of Arctic grayling marked versus those examined for marks (A) and versus those recaptured (B) and the Robson-Flick plot of average counts of unmarked Arctic grayling for each unique length of recaptured Arctic grayling (C) at Caribou Creek, 1981 and 1982.



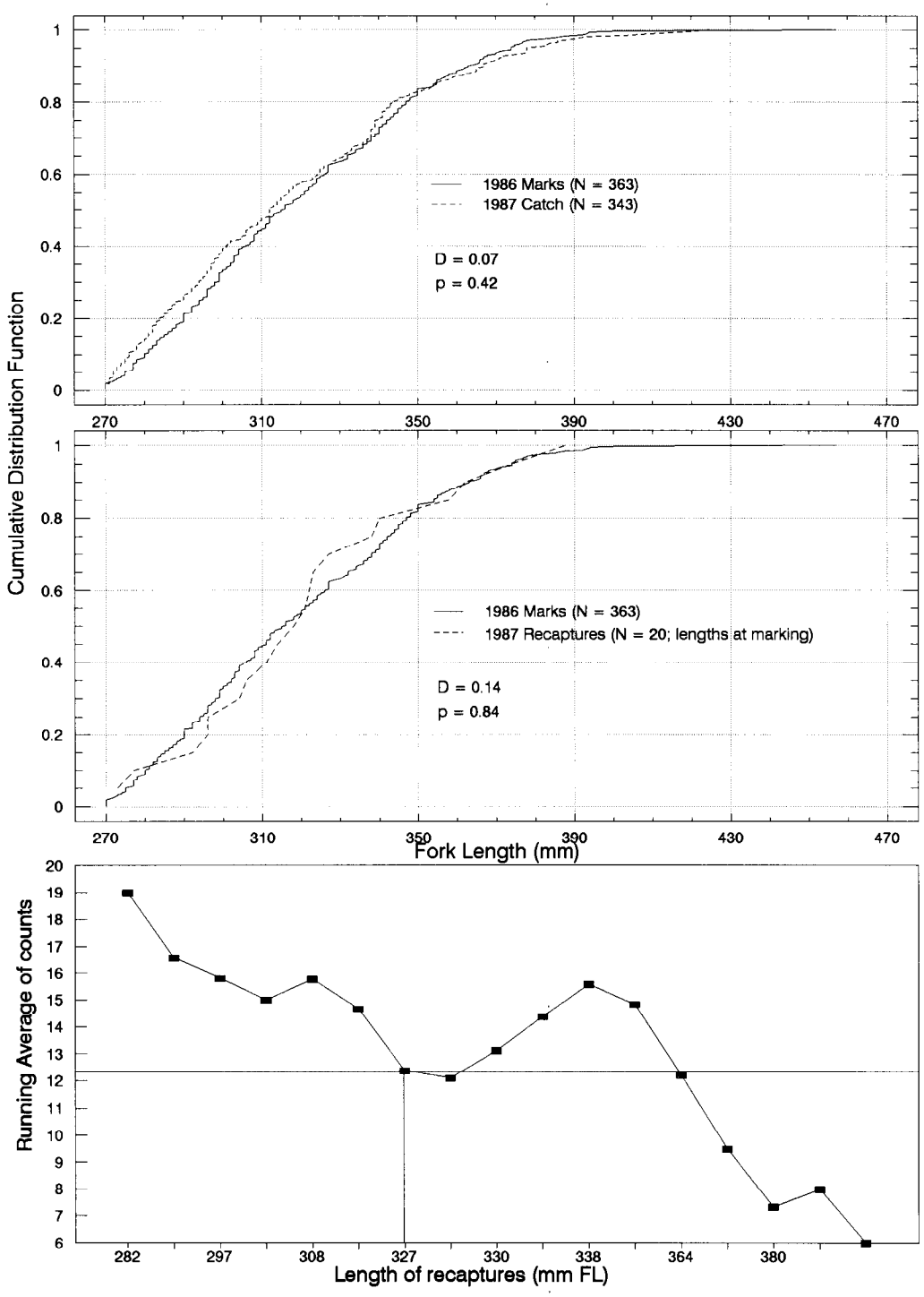
Appendix E3. Cumulative distribution functions of lengths of Arctic grayling marked versus those examined for marks (A) and versus those recaptured (B) and the Robson-Flick plot of average counts of unmarked Arctic grayling for each unique length of recaptured Arctic grayling (C) at Caribou Creek, 1982 and 1983.



Appendix E4. Cumulative distribution functions of lengths of Arctic grayling marked versus those examined for marks (A) and versus those recaptured (B) and the Robson-Flick plot of average counts of unmarked Arctic grayling for each unique length of recaptured Arctic grayling (C) at Caribou Creek, 1983 and 1984.



Appendix E5. Cumulative distribution functions of lengths of Arctic grayling marked versus those examined for marks (A) and versus those recaptured (B) and the Robson-Flick plot of average counts of unmarked Arctic grayling for each unique length of recaptured Arctic grayling (C) at Caribou Creek, 1985 and 1986.



Appendix E6. Cumulative distribution functions of lengths of Arctic grayling marked versus those examined for marks (A) and versus those recaptured (B) and the Robson-Flick plot of average counts of unmarked Arctic grayling for each unique length of recaptured Arctic grayling (C) at Caribou Creek, 1986 and 1987.