

**STATUS OF RAINBOW TROUT IN THE GOODNEWS RIVER,  
TOGIAK NATIONAL WILDLIFE REFUGE, ALASKA, 1993-1994**

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*Abstract.*—To monitor stock status, the rainbow trout population of the Goodnews River was sampled from June 1993 through August 1994. A total of 570 rainbow trout was captured using hook and line gear. Lengths ranged from 226-625 mm, and ages from scales ranged from 2-9 years. The length and age frequency distributions of rainbow trout from the North Fork were significantly different from that of the Middle Fork. Fifteen flights relocated 18 of 21 radio tagged rainbow trout between October 18, 1993 and August 18, 1994. Most fish moved less than 10 km throughout the year. The limited annual migration of rainbow trout shows that all waters where rainbow trout occur in the Goodnews Drainage should be considered important for spawning and overwintering.

Length and age frequency distributions were compared to data collected in 1988-1989. In 1993-1994, on both the Middle Fork drainage and the North Fork, fewer large rainbow trout were caught, and on the North Fork, a smaller maximum size was recorded. The age distributions of fish from the Middle Fork were significantly different from each other, while those from the North Fork were not different. While the changes may be attributed to natural variation, these populations warrant continued monitoring.

We recommend that long term monitoring continue and that the incidence and effects of hooking mortality on rainbow trout within the drainage be determined. Arctic grayling and *Salvelinus* spp. populations should continue to be monitored as part of the rainbow trout studies. To fulfil the Refuge objective to conserve fish and wildlife populations and habitats in their natural diversity, it is further recommended that public use be controlled at near present levels.

## Introduction

Wild rainbow trout *Oncorhynchus mykiss* stocks of southwest Alaska support a multimillion dollar per year sport fishing industry (Minard 1990). Angling opportunities on the Togiak National Wildlife Refuge (Refuge) are a primary attraction for visitors from around the world. In addition to rainbow trout, species targeted by anglers include: chinook salmon *O. tshawytscha*, coho salmon *O. kisutch*, Dolly Varden *Salvelinus malma*, Arctic char *S. alpinus*, and Arctic grayling *Thymallus arcticus* (Rob MacDonald, U.S. Fish & Wildlife Service, personal communication). Public use and fishing effort on Refuge rivers has increased significantly since the early 1980's. Sport fishing effort on the Goodnews River increased from an estimated 1,105 use days in 1981 (U.S. Fish and Wildlife Service 1990) to 2,886 use days in 1992 (MacDonald 1993). As high levels of use continue, both the number and size of fish could decrease.

In addition to the sport fishery, rainbow trout contribute to other fisheries. Some rainbow trout are captured incidentally in the Pacific salmon gillnet fishery. Rainbow trout have historically composed part of the subsistence harvest (Wolfe 1984), and there are directed

harvests of rainbow trout with hook and line ice fisheries (Mark Lisac, U. S. Fish and Wildlife Service, personal communication). The magnitude of these fisheries are unknown. In 1992, the Federal Subsistence Board recognized the rainbow trout as a valid subsistence species on non-navigable waters of the Refuge. Restricting the fishery to non-navigable waters generated concern that subsistence users would be forced to concentrate their harvest within rainbow trout spawning areas. Because no information on the rainbow trout spawning locations was available, it was hypothesized that rainbow trout from the navigable portion of the river would migrate to the small tributaries to spawn. Concentrating the harvest on the spawning segment of the population could have serious biological consequence for the entire population.

One of the primary purposes of the Refuge is to conserve fish and wildlife species and habitats in their natural diversity. The Fisheries Management Plan for the Refuge (U.S. Fish and Wildlife Service 1990) and State rainbow trout management plan (Alaska Department of Fish and Game 1990) established a wild stock management policy for rainbow trout stocks within southwest Alaska. The wild stock management concept emphasizes opportunities to catch fish from naturally reproducing populations while preserving their historic size and age compositions. Due to the popularity of rainbow trout as a sport species, the Refuge Fisheries Management Plan identified rainbow trout as an indicator species to assess the health of a river system and to assess potential impacts of man's activities. This requires the periodic evaluation of the Goodnews River's rainbow trout population.

Information concerning Goodnews River rainbow trout dates from 1975 when the Alaska Department of Fish and Game (Department) obtained a sample of 74 rainbow trout from the North Fork (Alt 1977). In 1985, the Department captured 92 rainbow trout on the Middle Fork of the Goodnews River (Alt 1986). From 1988 through 1989, the U. S. Fish and Wildlife Service (Service) conducted the first of the periodic evaluations of the rainbow trout population as outlined in the Refuge Fisheries Management Plan. Three hundred and eighty seven 387 rainbow trout were sampled from all forks of the Goodnews River (Irving and Faustini 1993). This investigation concluded that fishing pressure on the Goodnews River apparently did not have an excessive impact on the population, but that the population probably did not have the capacity to support significant increases in fishing pressure without a decrease in the abundance of the older fish (Irving and Faustini 1993).

The King Salmon Fishery Resource Office conducted the second periodic evaluation during 1993-1994. The goals of the study were to re-evaluate the status of the rainbow trout, and to provide information necessary to develop specific management objectives. Information was also collected on Arctic grayling and char *Salvelinus* spp. The specific objectives were to:

1. Determine the length distribution and mean length at age of rainbow trout vulnerable to the sport fishery.
2. Estimate annual survival of rainbow trout vulnerable to the sport fishery.

3. Compare the length distribution, length at age, age structure, and survival parameters with historical information.
4. Monitor seasonal changes in rainbow trout distribution in the Goodnews River drainage.
5. Describe the length and age structure of Arctic grayling captured while sampling for rainbow trout.
6. Describe the length structure of *Salvelinus* spp. captured while sampling for rainbow trout.

### **Study Area**

The Goodnews River originates in the Togiak National Wildlife Refuge where its three forks flow southwest into Goodnews Bay (Figure 1). The Goodnews River drains approximately 2,600 square kilometers in the Auklun Mountains. The North Fork is the major branch and flows approximately 75.5 km to Goodnews Bay. The Middle Fork is a 67.5 km long major tributary which parallels the North Fork and joins it near the bay. The main tributary to the Middle Fork is the Kukaktlik River. The South Fork is the smallest and shortest of the forks. The upper 40.2 km of the North Fork and upper 43.8 km of the Middle Fork are within Refuge boundaries.

The climate of the area is moderate, polar maritime, characterized by moderate winds, protracted cloud cover and frequent precipitation. Average summer air temperatures range from 3 to 19 °C and winter air temperatures range from -16 to -1 °C (U.S. Fish and Wildlife Service 1991). The riparian habitat consists of willow, alder, cottonwood and tundra vegetation.

### **Methods**

#### *Length Composition*

Sampling occurred from June through September 1993 and 1994. In 1993, a base camp was set up on the North Fork at km 45, and outboard jet boats were used to access the North and Middle Forks. One float trip was conducted from July 30 to August 4 to sample rainbow trout from Kukaktlim Lake to the mouth of the Middle Fork. In 1994, samples were collected during three float trips. Two float trips were conducted on the North Fork (June 29 to July 5, and August 5 to 9), from Goodnews Lake to the village. One float trip was conducted on the Middle Fork, from Kukaktlim Lake to the mouth of the Middle Fork during July 15 to 20.

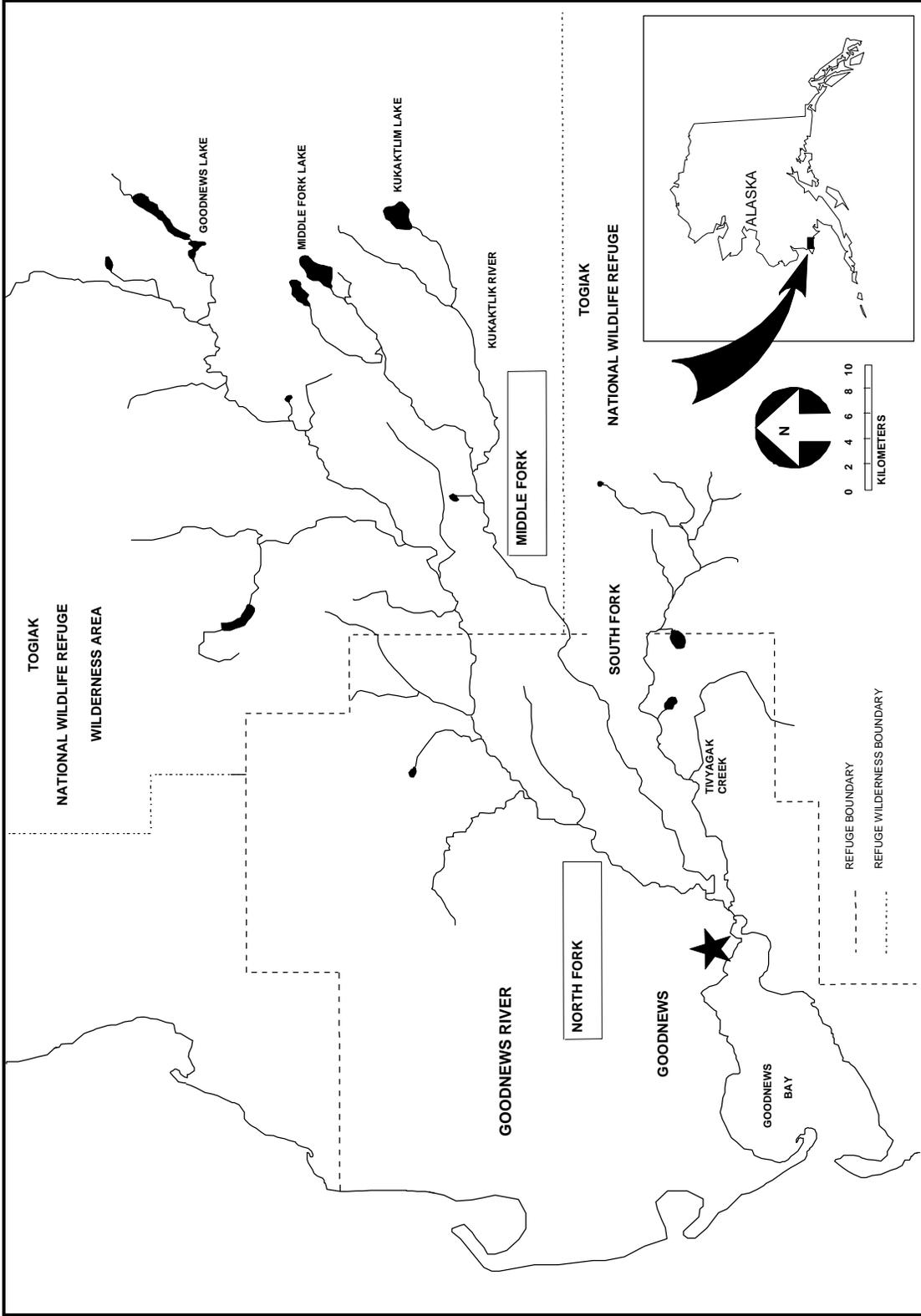


Figure 1.-Goodnews River drainage, Togiak National Wildlife Refuge, Alaska..

Data were organized into four main sets. First, two geographical groups were created: (1) the North Fork; and (2) the Middle Fork, including the Kukaktlic River. These two groups were further sorted into two temporal groups: (1) historic (1988-1989); and (2) current (1993-1994). Rainbow trout were measured for fork length to the nearest millimeter (mm). Length distributions of the current and historical data were compared between geographic groups with a Kolmogorov-Smirnov (K-S) two sample test ( $\alpha=0.05$ ) (Sokal and Rohlf 1981).

The data collected in 1993-1994 were intended for comparison to rainbow trout data from 1988-1989. Sampling in 1988-1989 included the use of electrofishing equipment and minnow traps to capture juvenile rainbow trout. However, in 1993-1994, rainbow trout were captured only by hook and line with single hook artificial lures. Therefore, for analysis and comparisons, only data from rainbow trout captured by hook and line during both studies were used. Due to small sample sizes, no attempt was made to quantitatively compare the rainbow trout data collected in the South Fork (N=30 in 1988; N=8 in 1993).

#### *Age Composition*

Scales were collected from the preferred scale area (Jearld 1983) and were aged according to Koo (1962). Scale ages were interpreted by two readers with a microfiche reader, and disagreements were resolved by conference. Regenerated scales were discarded. Age frequency distributions between and among temporal and geographical groups were compared with a G-test ( $\alpha=0.05$ ) (Sokal and Rohlf 1981).

#### *Survival Estimates*

Annual survival estimates were calculated from catch curve analysis utilizing a variable survival and unknown recruitment model (Everhart and Youngs 1981). The model used only the ages of fully recruited rainbow trout. The first year beyond the modal age of the catch curve was considered the youngest fully recruited age (Ricker 1975). The variance of this estimator is not exact (Everhart and Youngs 1981), and could not be calculated.

#### *Movement*

*Radio telemetry.*—From August 23 to September 14 1993, 21 ATS (Advanced Telemetry Systems, Ipsilanti, MN) radio transmitters (model six) were surgically implanted into rainbow trout captured in the Goodnews River. Transmitters operated in the 40 and 41 MHz range, and individual frequencies were separated by at least 20 KHz. Transmitters were 78 mm long, 17 mm in diameter, weighed 28 g, and contained loop antennae. The smallest implanted fish weighed 1,400 g based on the criterion of Winter (1983), where transmitter weight should not exceed two per cent of fish weight.

Fish were captured by hook and line and anesthetized to stage 4 (Summerfelt and Smith 1990) with MS-222. Surgical procedures followed Summerfelt and Smith (1990). The gills of each fish were continually bathed with stream water during surgery. After surgery

each fish was held upright in gently flowing water to facilitate recovery. When each fish had regained equilibrium and was fully recovered, it was released in a protected area of the stream.

Implanted fish were monitored by an ATS scanner/receiver with fixed wing aircraft flying at approximately 140 km/h and 300 m above the ground. On each flight the lower 40 km of the Middle Fork and the area downstream of the confluence of the Middle and North forks (mainstem) were searched a minimum of three times. The lower 40 km of the North Fork, the lower 20 km of the South Fork, the lower 10 km of Tivyagak Creek, and the lower 10 km of the Kukaktlik River were searched at least once each flight. During spawning season (late April-early June), the upper portions of the main tributaries were searched once per flight, in addition to the flight pattern described above. From October 1993 to March 1994 relocation of the implanted fish was attempted every six weeks. During April through June 1994 aerial tracking was conducted every two weeks. Aerial tracking was conducted monthly during July and August 1993.

*Floy tags.*—All captured and released rainbow trout larger than 250 mm were marked with Floy anchor tags. Adipose fins were clipped as a secondary mark to assess tag loss. Location and date of all recaptured rainbow trout were documented.

#### *Arctic Grayling and Char*

Lengths and scales were collected from Arctic grayling captured while sampling for rainbow trout. All fish were identified to species except Dolly Varden and Arctic char. They are referred to as *Salvelinus* spp. in this report. Lengths were collected from *Salvelinus* spp. captured while sampling for rainbow trout.

Sampling area and methods were consistent between the current and historic studies. Therefore, the capture ratios of rainbow trout to Arctic grayling, and rainbow trout to *Salvelinus* spp. were calculated and compared between the two studies to indicate whether relative CPUE among the species had changed.

## **Results**

#### *Length Composition*

Using hook and line gear, 342 rainbow trout were sampled during 1993, and 228 in 1994 (Table 1). Fork lengths of rainbow trout ranged from 226-625 mm for the current sample (1993-1994). The K-S test detected no differences in the cumulative length distributions between 1993 and 1994 for each geographic group (North Fork,  $D=0.10$ ,  $P=0.60$ ; Middle Fork,  $D=0.15$ ,  $P=0.28$ ; Kukaktlik River,  $D=0.15$ ,  $P=0.94$ ); thus the data from the two years were pooled. Similarly, the K-S test detected no difference in the cumulative length

TABLE 1.-Sample size for rainbow trout captured by hook and line in the Goodnews River, 1993-1994 and 1988-1989.

Drainage	Sample Year			
	1994	1993	1989	1988
North Fork	154	88	25	168
Middle Fork	55	215	85	37
Kukaktlik River	19	29	23	0
South Fork	30	0	8	0

distribution between the current samples of the Middle Fork and the Kukaktlik River ( $D=0.18$ ,  $P=0.14$ ), and these data were combined and referred to as the Middle Fork drainage. Cumulative length distributions of the current sample between geographic group (North Fork 1993-1994 vs. Middle Fork drainage 1993-1994) were significantly different ( $D=0.23$ ,  $P<0.001$ ), with fish from the North Fork being smaller (Figure 2). Cumulative length distributions of historic and current data were compared by geographic group. The length distributions were significantly smaller in the current sample for both the Middle Fork drainage ( $D=0.16$ ,  $P=0.01$ ) (Figure 3), and the North Fork ( $D=0.14$ ,  $P=0.02$ ) (Figure 4).

#### *Age Composition*

From the current sample, scales from 552 rainbow trout were examined; 6 scales (2%) were regenerated and discarded. The eight age samples from the South Fork were excluded from further analysis. The remaining 538 scale age samples from the North and Middle Forks were compared to 246 scale-aged rainbow trout from these geographic areas in 1988-1989 (Figure 5). Scale ages ranged from 2-9 years for 1993-1994 and 2-8 for 1988-1989 (Table 2). The age distributions of the current sample between geographic groups were significantly different ( $P<0.05$ ). Comparing current with historic data, the age distributions of the North Fork were not significantly different ( $P>0.50$ ), and they were significantly different for the Middle Fork ( $P<0.01$ ).

Mean fork lengths at age are summarized in Table 2. The current and historic samples were compared within their geographic groups. Generally, the current mean length at age was larger for fish aged 3-5, but smaller for fish aged 6-8.

#### *Survival Estimates*

In the North Fork, first recruitment to hook and line gear of rainbow trout in 1993-1994 occurred at 250 mm at age 2. In 1988-1989, the smallest fish captured by hook and line was 278 mm and age 3. Based on the catch curve rainbow trout became fully recruited at ages 5 and 6. In the Middle Fork drainage, first recruitment in 1993-1994 occurred at 226 mm at age 2. In 1988-1989, it was 163 mm and age 2. Rainbow trout became fully recruited at age 7. Estimates of annual survival rates were not calculated due to an inadequate sample size.

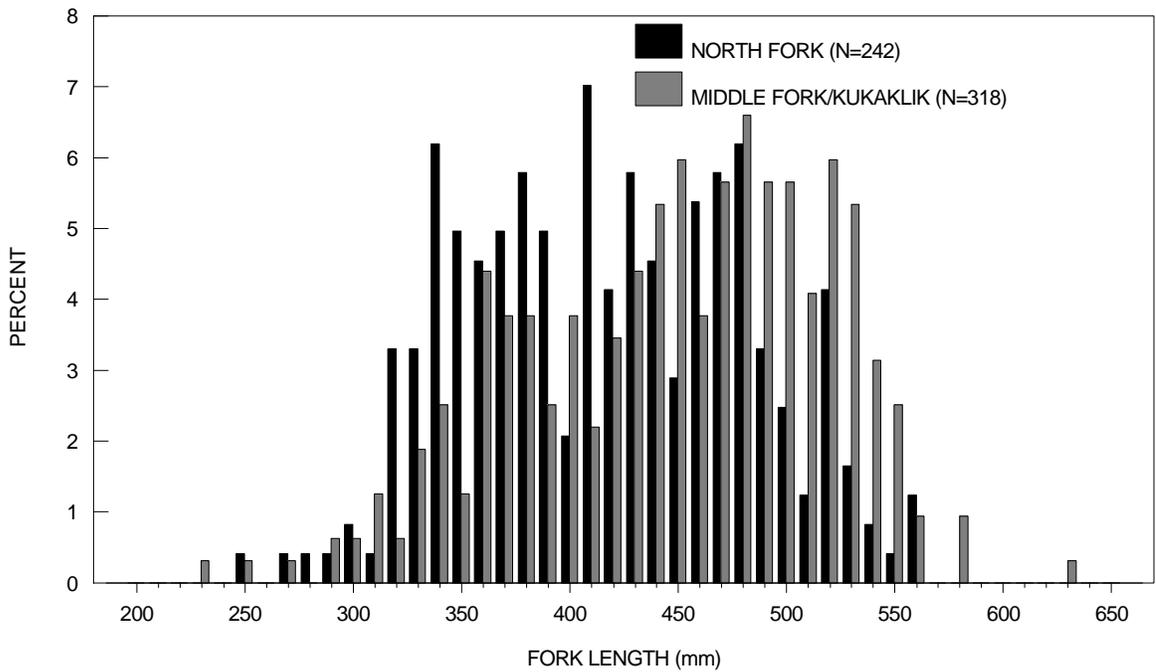
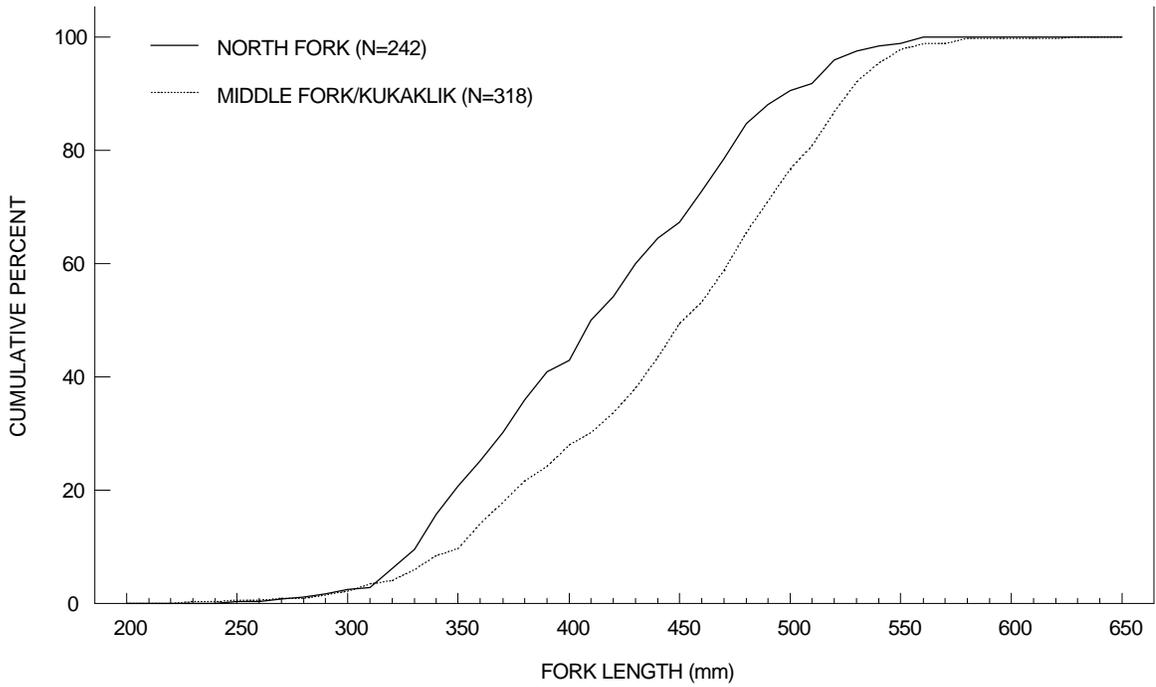


Figure 2.-Cumulative length frequency and length frequency of rainbow trout captured by hook and line from the Goodnews River drainage, 1993-1994.

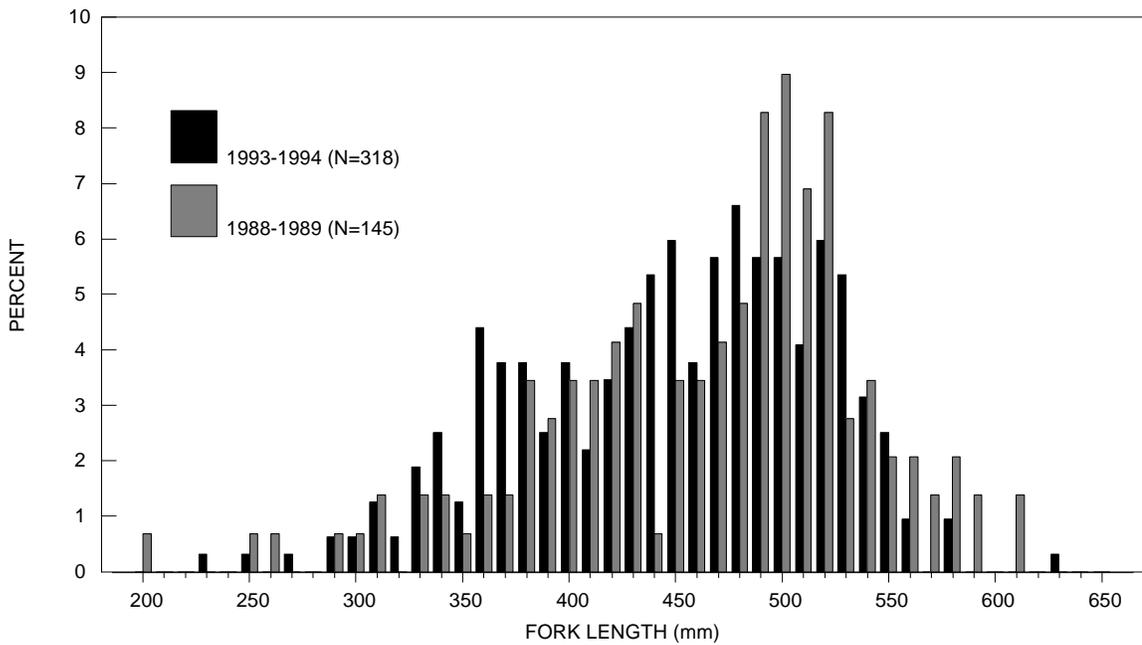
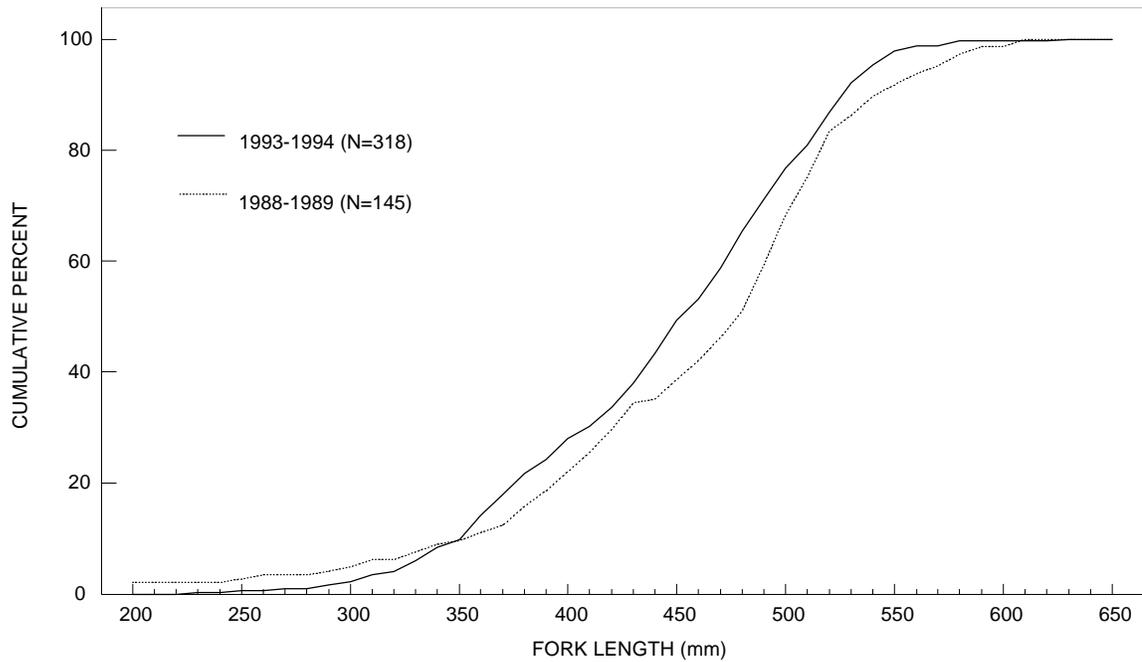


Figure 3.-Cumulative length frequency and length frequency of rainbow trout captured by hook and line from the Middle Fork and Kukaktlik River of the Goodnews River, 1988-1989 and 1993-1994.

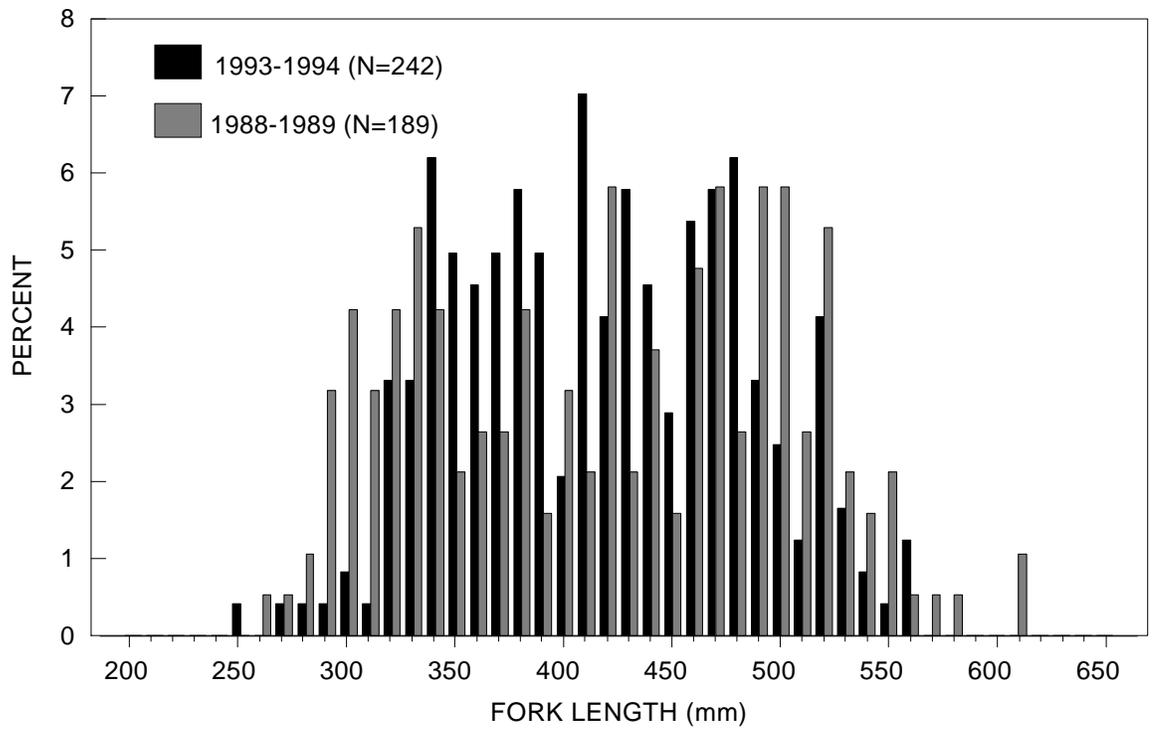
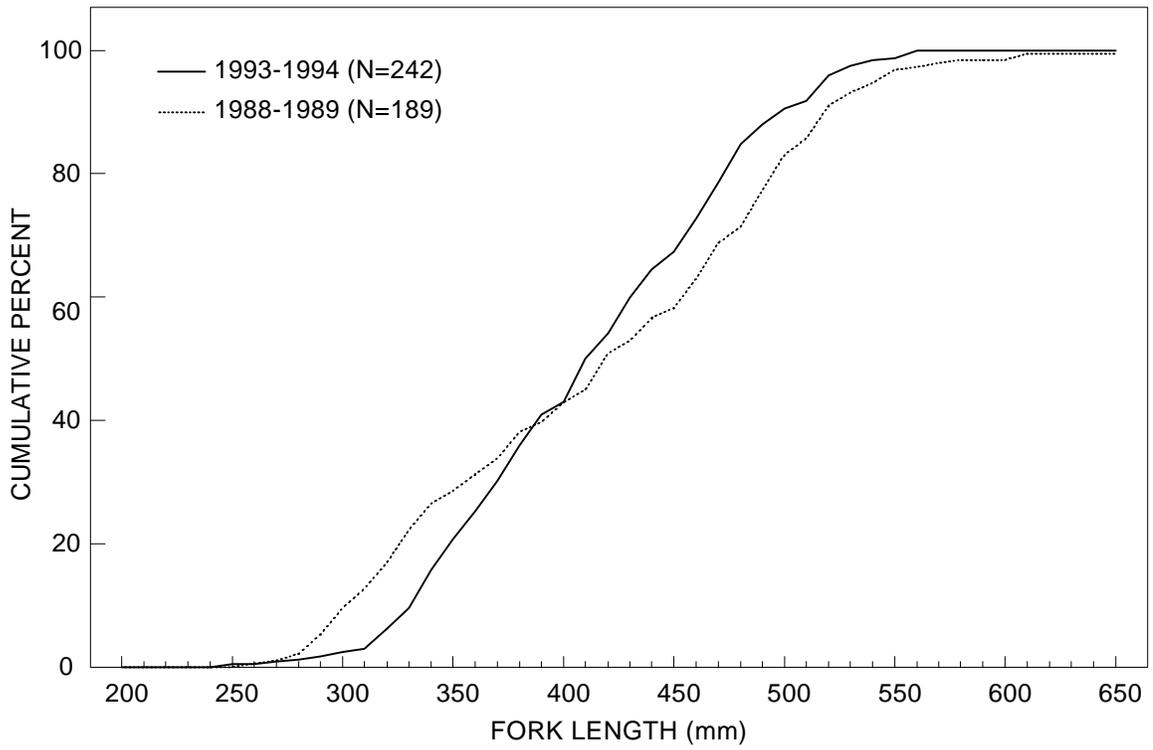


Figure 4.-Cumulative length frequency and length frequency of rainbow trout captured by hook and line from the North Fork of the Goodnews River, 1988-1989 and 1993-1994.

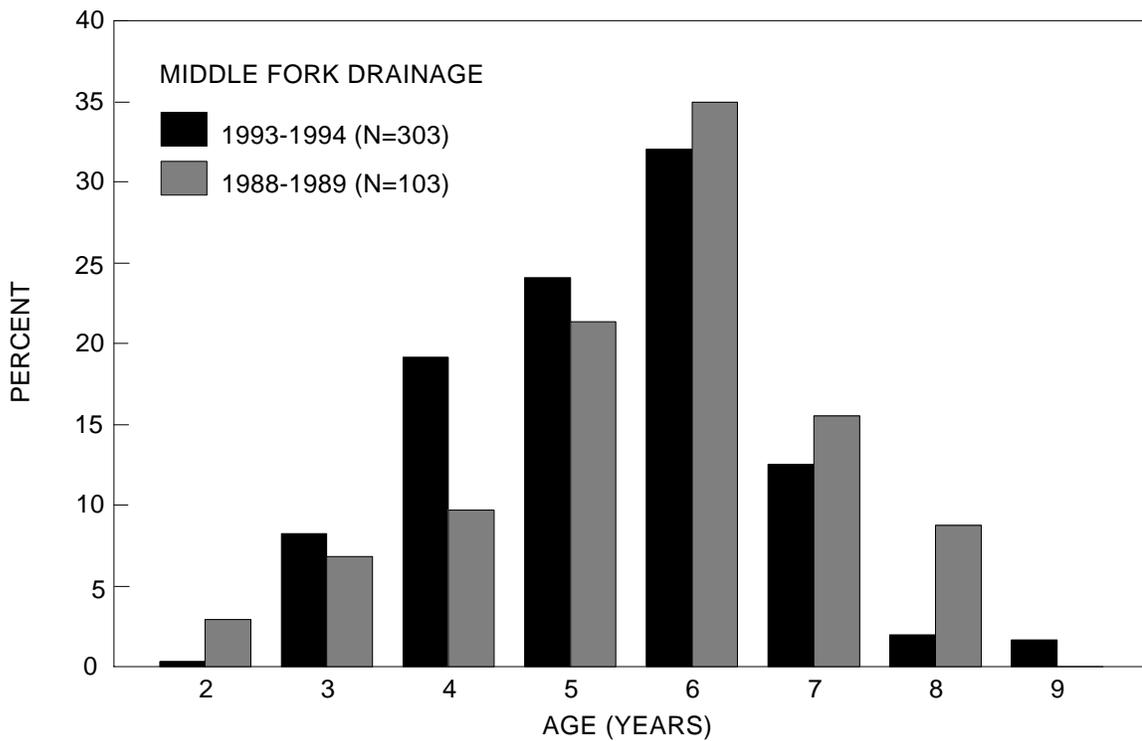
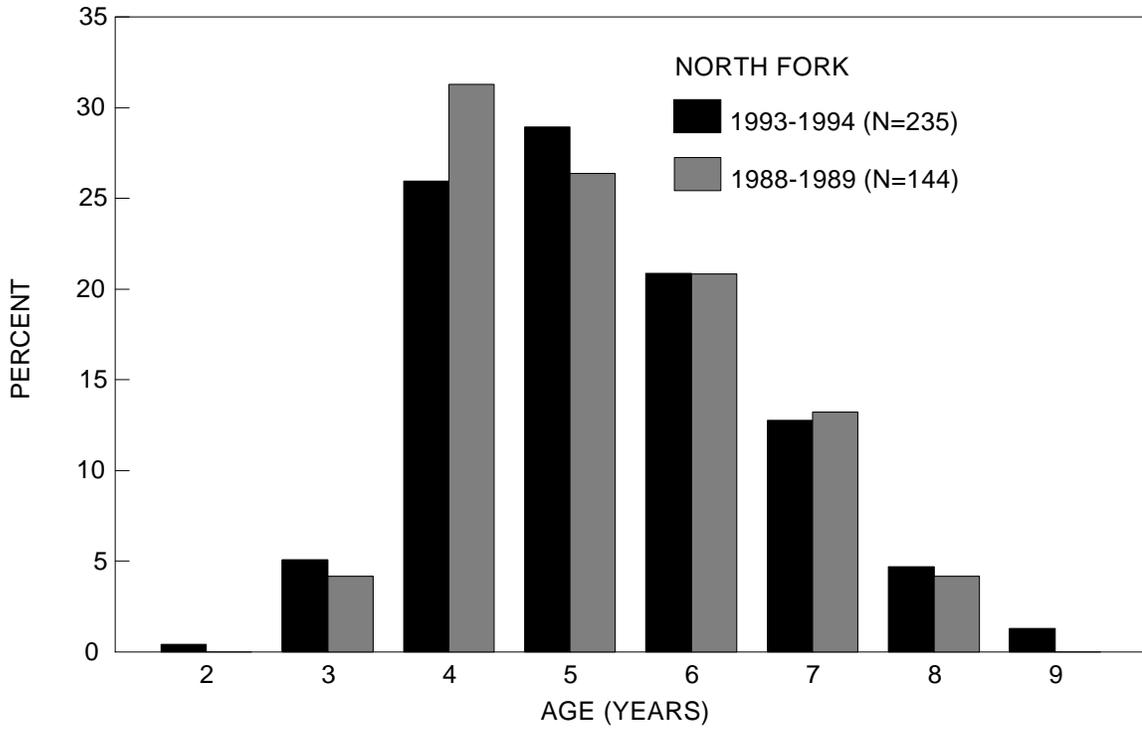


Figure 5.-Age frequency of rainbow trout captured by hook and line in the North Fork and Middle Fork drainage of the Goodnews River, 1988-1989 and 1993-1994.

TABLE 2.-Length at age and number of rainbow trout captured by hook and line in the North and Middle Forks of the Goodnews River during 1993-1994 and 1988-1989.

Age	1993-1994				1988-1989			
	Fork length (mm)				Fork length (mm)			
	<i>N</i>	Mean	SD	Range	<i>N</i>	Mean	SD	Range
<b>North Fork</b>								
2	1	250	-	-	-	-	-	-
3	12	326	29	262-36	6	294	14	278-321
4	61	355	33	285-43	45	321	32	255-433
5	68	415	48	335-52	38	409	44	326-550
6	49	437	37	346-50	30	464	32	378-520
7	30	478	38	405-55	19	493	33	412-545
8	11	524	24	470-55	6	511	24	471-539
9	3	502	17	490-52	-	-	-	-
<b>Middle Fork Drainage</b>								
2	1	226	-	-	2	180	17	163-197
3	25	323	34	245-40	7	294	32	243-340
4	58	378	32	310-45	10	366	18	328-383
5	73	446	42	357-55	22	418	30	377-497
6	97	479	38	370-56	36	486	37	400-555
7	38	506	37	380-55	16	504	17	455-530
8	6	525	33	464-57	9	539	38	482-604
9	5	559	35	525-62	-	-	-	-

## Movement

*Radio telemetry.*—Twenty one transmitters were implanted in rainbow trout: 17 from the Middle Fork; 1 from the Kukaktlik River; 2 from Tivyagak Creek of the South Fork; and 1 from the North Fork. Fork lengths and weights of fish that received transmitters ranged from 502 mm and 1,500 g to 557 mm and 2,150 g. One transmitter was not relocated after surgery, and one was relocated only once early in the study. These two transmitters were assumed to have failed. Also, one transmitter was relocated five times at the mouth of the main river where it joined Goodnews Bay. Since this transmitter showed no upstream or downstream movement, and this area does not provide year-round habitat for rainbow trout, it was assumed that this fish died or expelled its transmitter. Therefore, valid data were obtained from 15 fish implanted in the Middle Fork, and one each from Tivyagak Creek, the North Fork, and Kukaktlik River. The scheduled November and February flights were postponed due to poor weather and equipment malfunction, and 15 flights were actually conducted. The number of relocations for an individual fish ranged from 1-14. The number of fish relocated per flight ranged from 2-17 (Appendix A). Where implanted rainbow trout are referred to individually, they are identified by the last three digits of their tag transmitter frequency (TF), as listed in Appendix A.

Throughout the aerial tracking, half of the 18 implanted rainbow trout remained within 10 km of their capture site. Of the nine fish that moved greater than 10 km, most travelled between 11-15 km (Table 3 and Appendix A). The maximum distance observed was exhibited by one fish (TF 380) that moved 47 km upstream and then returned 47 km downstream within a six week period. The minimum distance travelled was exhibited by three fish that remained within 2 km of their implantation sites throughout the study.

Table 3.-The distance radio tagged rainbow trout moved between implantation site and relocation sites in the Goodnews River during Fall 1993 to Summer 1994.

Relocation season	Number of fish			
	1-10 km	11-15km	16-20km	>20km
Fall <sup>a</sup>	10	2	1	
Winter <sup>b</sup>	11	5		
Spring <sup>c</sup>	13	2	2	1
Summer <sup>d</sup>	13		1	

<sup>a</sup> Fall = October 1993 (November flight canceled).

<sup>b</sup> Winter = December 1993 to March 1994.

<sup>c</sup> Spring = April to early June 1994.

<sup>d</sup> Summer = Late June to August 1994.

Of 13 fish relocated during the fall (October), three fish (TF 450, 340, and 220) moved more than 10 km from their surgery site. The remainder were relocated 0-5 km from their tagging site. A November flight was scheduled for inclusion with fall season data, but was cancelled due to poor weather conditions.

During the winter (December-March), 16 rainbow trout were relocated at least once. Four fish (TF 360, 200, 180, and 110) in addition to the three mentioned above, moved 10-15 km from their implantation site, presumably during November when no flights were conducted. However, within the winter season, fish exhibited very little movement. Fish moved from 0-4 km between relocations.

During spawning season (April-early June), all 18 rainbow trout were relocated. Most of the movement observed throughout the study occurred during this season. Five fish remained within 5 km of their overwintering range, six fish moved between 5-10 km, and five fish moved more than 10 km from their overwintering locations. For two fish (TF 450 and 950), the relocation during this period was the only relocation since the fall during the entire study. Both those fish were relocated within 5 km of their implantation site.

Fourteen fish were relocated during summer (late June-August). Fish exhibited the least amount of movement during this period. Fish moved from 0-2 km between relocations. Also, 12 of these 14 fish had moved back to within 2 km of their original implantation location.

*Floy tags.*—Seven individual rainbow trout were recaptured from 523 tagged fish during the current study. All of these fish were tagged and recaptured in the lower Middle Fork. One fish tagged in 1993 was recaptured in 1994, 10 km from its tagging site. This fish had been at liberty for 383 days. Another fish moved 16 km upstream during 53 days at liberty during 1993. The remaining fish were all recaptured in 1993 at their original tagging location over periods ranging from 0 to 46 days. No incidence of tag loss was observed.

#### *Arctic Grayling and Char*

In the current sample, 104 Arctic grayling were captured throughout the Goodnews River. Fork lengths ranged from 257-495 mm and ages from 3-8 years (Figure 6). The historic sample contained 131 Arctic grayling ranging from 275-510 mm. Fewer large Arctic grayling were sampled in the current study, and a smaller maximum size was recorded. The mean length for the population of the current sample was 398 mm, compared to 435 mm for the historic sample. Also, in 1993-1994, many grayling in the 300-350 mm range were captured, whereas samples in this size category were completely lacking in the historic sample (Figure 6).

In 1993-1994, more effort was required to catch each Arctic grayling. In both the current and historic studies, Arctic grayling were not specifically targeted; they were incidental to

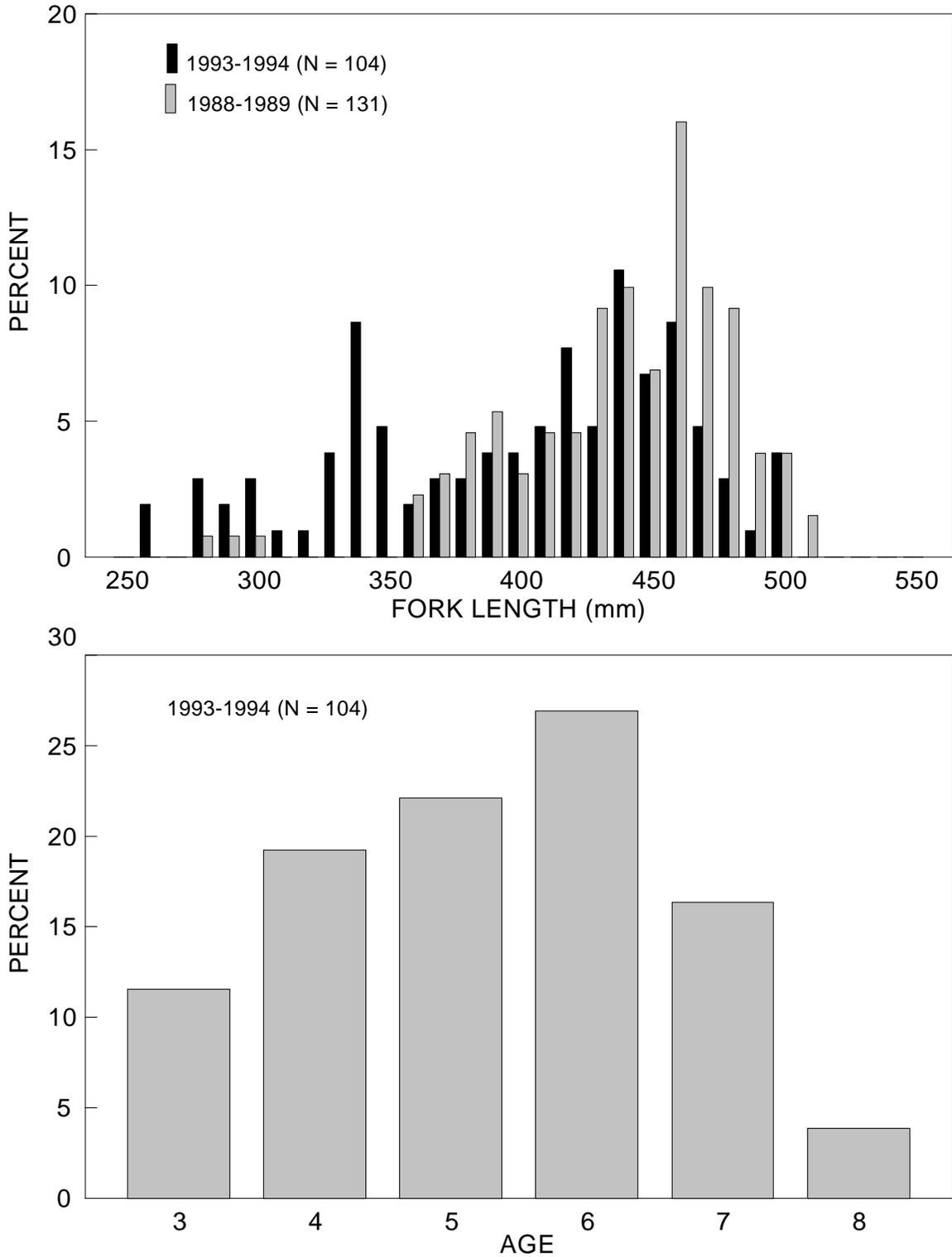


Figure 6.-Length frequency distribution of Arctic grayling from the Goodnews River, 1988-1989 and 1993-1994, and age frequency distribution of Arctic Grayling from the Goodnews River, 1993-1994.

the rainbow sample. Fishing effort was similar in both studies. In 1988-1989, the ratio of Arctic grayling to rainbow trout was 1:2.8; in 1993-1994, it was 1:5. The current data contain both a greater number of rainbow trout and fewer Arctic grayling than in 1988-1989.

The current sample contained 349 *Salvelinus* spp. which were captured throughout the Goodnews River drainage. They were not captured in large numbers until mid July. Only eight were captured before July 11, though sampling began June 23 in 1993 and June 29 in 1994. *Salvelinus* fork lengths ranged from 287-740 mm, compared with a range of 278-639 mm from 175 fish sampled in 1988-1989 (Figure 7).

Comparable effort was required to catch each *Salvelinus* in the current and historic samples. The capture of these fish was incidental to the rainbow trout sample. In 1988-1989, *Salvelinus* and rainbow trout were caught in a 1:2.1 ratio. In 1993-1994, the *Salvelinus* to rainbow trout ratio was 1:1.6. The current sample contained a higher proportion of fish greater than 600 mm, and a larger maximum size was noted.

## Discussion

### *Length, Age, and Survival*

The maximum length of rainbow trout captured from the Goodnews River in 1993-1994 was 625 mm while in 1988-1989 it was 686 mm. These lengths are within the range of values reported in other streams of southwest Alaska. While the largest fish sampled in the Agulupak River was 554 mm (Dunaway 1993), the lengths of the largest fish in Talarik Creek (Russell 1977) and the Naknek River (Burger and Gwartney 1986) were greater than 800 mm. The maximum length of rainbow trout appears to be dependent on the watershed sampled and is probably related to a combination of environmental and genetic factors.

Maximum recorded ages of rainbow trout from southwest Alaska systems are variable. The oldest reported scale ages from studies with large sample sizes ranged from 7 years in the Agulowak River (Riffe 1994) to 14 years from the Kvichak River and Naknek River systems (Minard and Dunaway 1991). The maximum age of 9 years from the Goodnews River were within the range of maximum ages reported from the region, but are less than reports from earlier Goodnews River samples. Alt (1977) reported a maximum age of 12 years from 66 rainbow trout from the North Fork. In 1985, he reported a maximum age of 10 years from 82 fish from the Middle Fork (Alt 1986).

Scale ages from rainbow trout are subject to error because: (1) slow growth produces compressed circuli with indistinct annuli; (2) scale margins are resorbed during spawning; (3) annuli often do not form during the first winter (Lentsch and Griffith 1987); and (4) within reader and between reader age estimation variability can effect the outcomes of population age composition analysis (Coggins 1994). Therefore, scale ages

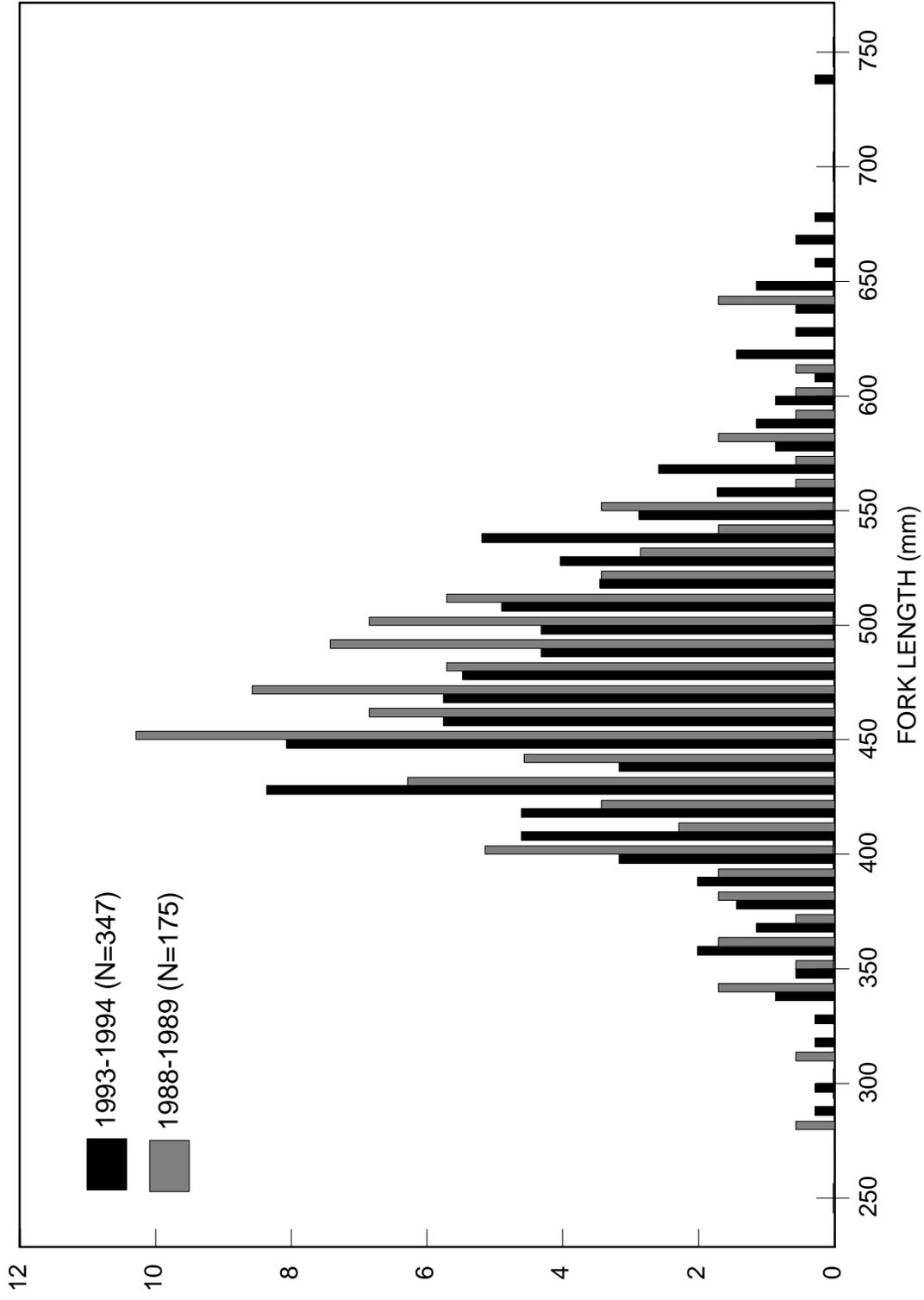


Figure 7.-Length frequency of *Salvelinus* spp. captured by hook and line from the Goodnews River, 1988-1989 and 1993-1994.

must be interpreted conservatively. However, the indication of the loss of the oldest age classes since Alt's studies are disturbing and support the argument that this population should be closely monitored.

The current North Fork rainbow trout population parameters are distinct from those of the Middle Fork drainage. There were significant differences in the length and age frequency distributions. Also, there was very little evidence of movement between these two drainages. The level and type of public use is also different on the North Fork and Middle Fork, and this could affect the populations differently. Therefore, the major forks of the Goodnews River should be evaluated and monitored individually.

In comparing of the current to historic population parameters on the Middle Fork drainage and the North Fork, the significant difference between the current and historic length distributions indicates that the size structure of these populations have changed. The significance in the K-S test relies on the single largest difference seen between the two distributions. The K-S test is sensitive, and the biological significance of the test results, if any, is inconclusive. However, in both the Middle Fork drainage and North Fork length distributions, there were fewer of the bigger rainbow trout in the most recent sample. This is perhaps of greater concern than the K-S test result. Although more rainbow trout were sampled in 1993-1994, fewer large fish were caught, and on the North Fork, a smaller maximum size was recorded. Because it is a Refuge objective to conserve fish and wildlife populations and habitats in their natural diversity, including size diversity, the potential loss of the larger, older rainbow trout is disturbing.

On the North Fork, though the age frequency distributions between current and historic data were not significantly different, the mean length at age had changed. For 1993-1994, the younger rainbow trout (aged 3-5) had a larger average length at age, and the older fish were smaller. This suggests compensatory growth (Healey 1978). If the large fish are being removed from the population, smaller fish will grow at an accelerated rate to fill the void left by the large fish. The occurrence of compensatory growth on the North Fork supports the hypothesis that the larger fish are being removed from the population by some mechanism.

On the Middle Fork drainage, the age distribution has changed, though the modal age of this population has remained constant at age 6. The current age distribution is skewed left. It has a greater percentage of the population aged 2-5 years, and fewer fish aged older than 6. The current sample appears to contain a higher percentage of younger fish. The observed differences may be due to ageing error, or the progression of strong and weak year classes, but the data are not conclusive. The Middle Fork length at age data show a similar trend as on the North Fork. For 1993-1994, the younger rainbow trout (aged 3-5) had a larger average length at age, and the older fish were smaller.

Several use related factors may cause the apparent shortage of large rainbow trout in the current Goodnews River samples: (1) sport harvest; (2) hooking mortality; and (3) subsistence harvest. Larger, older fish may be selectively harvested for food or as a trophy. The Goodnews River receives relatively light angling pressure, but it is slowly

increasing and most use occurs on the North Fork (R. MacDonald, U.S. Fish and Wildlife Service, personal communication). From 1989-1993, the ADFG statewide harvest report indicates that angler days and catch have shown an increasing trend, while harvest has steadily dropped (Mills 1990-1994). The reduction in harvest is because most sport fishermen in southwest Alaska voluntarily practice catch and release fishing techniques. Yet hooking and handling mortality from catch and release fishing may be a factor in the decline of large fish. Based on the catch estimates from 1991-1993 (Mills 1990-1993) and assuming a 10% hooking mortality for rainbow trout (Horton and Wilson-Jacobs 1985), 128-400 rainbow trout could have died annually from hooking mortality throughout the river. Hooking mortality would affect all sizes, but larger fish are more susceptible to death (Taylor and White 1992). Subsistence harvest is not quantified and the magnitude of rainbow trout harvest is unknown. It appears, however, that most subsistence fishing occurs low in the drainage, outside the home range of most rainbow trout. Therefore, it seems that hooking mortality has the greatest potential to affect the rainbow trout population.

The Goodnews River rainbow trout population is assumed to have variable survival and unknown recruitment. An estimator of survival factoring in these conditions turned out to be unreliable. Therefore, they were not reported. Because rainbow trout become fully recruited at a relatively older age, the majority of the population is not included into the model, leaving an inadequate sample size for the calculations, even when the North Fork and Middle Fork drainage samples were combined.

### *Movement*

Resident rainbow trout are generally not known for extensive travel (Morrow 1980). The majority of radio tagged and Floy tagged rainbow trout on the Goodnews River did not move substantially during any season.

However, rainbow trout from some lake populations in southwest Alaska have exhibited considerable movement. Floy tagged fish from the Kvichak River were recaptured in the Copper River, approximately 80 km across Lake Iliamna (Minard et al. 1992). Radio tagged rainbow trout from the Naknek River moved approximately 70 km into the Bay of Islands area of Naknek Lake (Burger and Gwartney 1986). However, these populations are associated with large lake systems that allow extensive movement to feeding, spawning, and overwintering areas.

The assignment of dates for overwintering and spawning periods was arbitrary. However, it did provide an indication of fish movements in response to seasonal demands. Of the nine radio tagged rainbow trout that traveled 10 or more km from their transmitter implantation site, most moved only once during the year, and exhibited very little movement otherwise. In four instances (TF 450, 360, 340, and 220), the fish moved 14-16 km upstream or downstream between the time they experienced surgery and the first relocation. These fish possibly moved as a reaction to the implantation process. In three of these cases, the fish eventually moved back within 5 km of their original capture sites. No data is available for the fourth fish. During the spawning season, three rainbow trout

(TF 380, 340, and 300) made upstream movements from 16-47 km. On subsequent relocation flights, all three fish had returned to within 2 km of their location prior to the movement. These three fish did not journey to a common location, and no attempt to identify a specific spawning reach was made. It is likely that spawning occurs throughout the drainage. During late fall and early winter, four rainbow trout (TF 340, 200, 180, and 110) moved downstream 10 or more km from their implantation site. Rainbow trout #340 was previously discussed. Fish with TF 200 and 180 possibly moved downstream to access suitable overwintering sites. These fish were from the Kukaktlik River and the upper reach of the Middle Fork. The drainage in this area can form anchor ice during the winter. The low occurrence of movement by radio tagged and Floy tagged fish during any season indicates that the Goodnews River, particularly the Middle Fork from river kilometer (rkm) 8-22, provides quality habitat for rainbow trout throughout the year. In summary, fish movements were limited, but those that did occur seemed to fall into three categories: (1) as a stress response to surgery; (2) to travel upstream to a spawning site; and (3) to travel downstream to overwintering sites.

Because only rainbow trout with a body weight of 1,400 g or greater (translating to fork lengths of over 500 mm) were fitted with radio transmitters, the data are only applicable to larger fish. Smaller rainbow trout may exhibit different patterns of seasonal movement.

#### *Arctic grayling and Char*

The fork lengths and ages of Arctic grayling and *Salvelinus* spp. from the Goodnews River were typical for these species in Alaska (Morrow 1980). Several life history strategies are exhibited by *Salvelinus* in Alaska (Armstrong and Morrow 1980) including stream resident and anadromous forms. The presence of anadromous *Salvelinus* in the Goodnews River is indicated by a large influx of big fish (greater than 700 mm) into the drainage in July.

The *Salvelinus* population appears stable when the current and historic samples are compared. The biggest observable difference is that fish greater than 640 mm were caught in 1993-1994. This is probably due to the larger sample size of the current sample.

The smaller average length of Arctic grayling and the apparent decrease in CPUE suggests that the numbers and size of this species are decreasing. While this observation is not conclusive, it does emphasize that Arctic grayling should be monitored as well as rainbow trout. The peak in the length frequency from 310-350 mm is interesting, especially as no fish from this size range was sampled in 1988-1989. The difference is likely due to a progression of strong and weak cohorts.

#### *Conclusions and Recommendations*

The scale ageing technique is subject to bias between samples and between readers, and this can account for many apparent changes in the rainbow trout population. However, reexamination of a subset of the historic scale samples indicated that age estimates were

consistent between studies. Still, since analysis and conclusions of the Goodnews River rainbow trout population are based on scale ages, a conservative approach should be made for recommendations.

The changes noted in the current Goodnews River samples are subtle, making firm conclusions difficult. Because rainbow trout exhibit very little movement during the summer, they may be susceptible to capture several times during a season. With the high potential for multiple captures, hooking mortality may be a major factor, especially for older fish. As such, despite the low effort and harvest, few large fish may be available in the fishery. Although the data from 1975 and 1985 were not quantitatively evaluated, it does emphasize the potential loss of the oldest age classes of rainbow trout over the long term. This possible trend needs to be evaluated closely. This rainbow trout population probably does not have the capacity to support significant increases in fishing pressure without a decrease in the size and age composition. To fulfill the Refuge objective to conserve fish and wildlife populations and habitats in their natural diversity, it is recommended that public use not be increased significantly over the present level.

To further describe the population structure of rainbow trout and assess the effects that fisheries have on this stock, the following actions are recommended: (1) replicate this study every five years as part of long term monitoring program; a replication of the radio tagging will confirm the small home ranges that these fish occupy; (2) with the help of the Refuge river rangers, determine the effort, catch, and harvest of rainbow trout by subsistence and sport fisheries on the North Fork; (3) continue to annually monitor use on the entire river through special use permits and the statewide harvest survey; (4) determine the incidence and effects of hooking mortality on rainbow trout within the drainage; and (5) continue to monitor Arctic grayling and *Salvelinus* spp. populations in conjunction with the rainbow trout studies.

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Appendix A.-Aerial relocations (km) of radio tagged rainbow trout from the Goodnews River 1993-1994. All transmitters were implanted from August 23 to September 14 1993.

		Tag Frequency (KHz)																
		Implantation Location																
Flight Date	41.450	41.380	41.360	41.340	41.300	41.280	41.260	41.220	41.200	41.180	41.110	40.980	40.950	40.910	40.890	40.870	40.850	40.830
	NF 39	MF 8	MF 14	MF 14	MF 6	MF 24	MF 18	MF 8	KR 3	MF 48	MF 27	MF 21	MF 21	TC 0	MF 16	MF 13	MF 13	MF 10
	<b>Fall Relocations<sup>a</sup></b>																	
18-Oct-93	NF 23	-	MF 0	MF 24	MF 18	MF 23	MF 47	MF 43	MF 26	MF 21	-	TC 0	MF 16	MF 13	-	MF 8		
	<b>Winter Relocations</b>																	
07-Dec-93	-	-	MF 13	MF 5	MF 23	-	MF 22	-	MF 16	MF 20	-	-	MF 16	MF 13	MF 13	MF 9		
27-Jan-94	-	MF 8	MF 0	MF 13	MF 4	MF 19	MF 37	MF 39	MF 16	MF 19	-	SF 11	MF 13	MF 13	MF 11	MF 8		
11-Mar-94	-	MF 8	MF 3	MF 11	MF 5	MF 18	-	MF 20	MF 39	MF 19	MF 21	-	-	MF 13	-	MF 9		
31-Mar-94	-	MF 11	MF 1	MF 11	MF 5	MF 22	MF 17	MF 19	MF 39	MF 19	MF 21	-	-	MF 16	MF 13	MF 11	MF 10	
	<b>Spring Relocations<sup>a</sup></b>																	
15-Apr-94	NF 43	-	MF 11	MF 20	-	-	-	-	MF 21	-	-	-	-	-	-	-	-	-
23-Apr-94	-	MF 2	-	MF 22	MF 17	MF 19	MF 40	MF 43	MF 19	MF 21	-	-	MF 16	-	-	-	-	-
29-Apr-94	-	MF 4	-	MF 22	-	-	-	-	-	-	-	-	-	-	-	-	-	-
06-May-94	-	MF 9	MF 5	MF 14	MF 5	MF 24	MF 17	MF 24	MF 47	MF 45	MF 19	MF 24	MF 24	SF 13	MF 16	MF 21	MF 13	MF 10
18-May-94	-	-	MF 33	MF 5	MF 22	MF 17	MF 22	-	MF 43	MF 26	MF 21	-	SF 14	MF 22	MF 11	MF 13	MF 9	
31-May-94	-	KR 9	MF 16	-	MF 5	MF 22	MF 23	MF 27	-	MF 48	MF 31	MF 26	-	-	MF 15	MF 14	MF 14	MF 8
09-Jun-94	-	-	MF 13	MF 2	MF 21	MF 18	-	-	-	-	MF 20	-	SF 11	MF 14	MF 11	MF 13	MF 8	
	<b>Summer Relocations</b>																	
22-Jun-94	-	MF 9	-	MF 14	MF 5	MF 23	MF 16	-	KR 3	-	-	MF 20	-	SF 13	MF 16	MF 11	MF 11	MF 8
26-Jul-94	-	MF 5	-	MF 14	-	MF 23	-	-	KR 2	-	-	MF 23	-	-	MF 14	MF 14	-	MF 9
18-Aug-94	-	MF 6	-	MF 14	-	MF 22	-	MF 26	KR 3	MF 41	-	MF 21	-	TC 0	MF 16	MF 13	MF 13	-

<sup>a</sup> NF=North Fork; MF=Middle Fork; KR=Kukaklik River; TC=Tivyagak Creek; SF=South Fork.