Fishery Data Series No. 04-05

Nome River Arctic Grayling Restoration, Seward Peninsula, Alaska 2002 and 2003

by

Alfred L. DeCicco

May 2004

Alaska Department of Fish and Game **Division of Sport Fish**

Symbols and Abbreviations

The following symbols and abbreviations, and others approved for the Système International d'Unités (SI), are used in Division of Sport Fish Fishery Manuscripts, Fishery Data Series Reports, Fishery Management Reports, and Special Publications without definition.

Weights and measures (metric)

centimeter	cm
deciliter	dL
gram	g
hectare	ha
kilogram	kg
kilometer	km
liter	L
meter	m
milliliter	mL
millimeter	mm

Weights and measures (English)

cubic feet per second	ft^3/s
foot	ft
gallon	gal
inch	in
mile	mi
nautical mile	nmi
ounce	oz
pound	lb
quart	qt
yard	yd

Time and temperature

day	d
degrees Celsius	°C
degrees Fahrenheit	°F
degrees kelvin	K
hour	h
minute	min
second	s

Physics and chemistry

all atomic symbols	
alternating current	AC
ampere	A
calorie	cal
direct current	DC
hertz	Hz
horsepower	hp
hydrogen ion activity (negative log of)	pH
parts per million	ppm
parts per thousand	ppt, ‰
volts	V
watts	W

General

Alaska Administrative Code	AAC
all commonly accepted abbreviations	e.g., Mr., Mrs., AM, PM, etc.
all commonly accepted professional titles	e.g., Dr., Ph.D., R.N., etc.
at	@
compass directions:	
east	E
north	N
south	S
west	W
copyright	©
corporate suffixes:	
Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
District of Columbia	D.C.
et alii (and others)	et al.
et cetera (and so forth)	etc.
exempli gratia (for example)	e.g.
Federal Information Code	FIC
id est (that is)	i.e.
latitude or longitude	lat. or long.
monetary symbols (U.S.)	$, ¢
months (tables and figures): first three letters	Jan,...,Dec
registered trademark	®
trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S.C.	United States Code
U.S. state	use two-letter abbreviations (e.g., AK, WA)

Measures (fisheries)

fork length	FL
mideye-to-fork	MEF
mideye-to-tail-fork	METF
standard length	SL
total length	TL

Mathematics, statistics

all standard mathematical signs, symbols and abbreviations	
alternate hypothesis	H_A
base of natural logarithm	e
catch per unit effort	CPUE
coefficient of variation	CV
common test statistics	(F, t, χ^2, etc.)
confidence interval	CI
correlation coefficient (multiple)	R
correlation coefficient (simple)	r
covariance	cov
degree (angular)	°
degrees of freedom	df
expected value	E
greater than	>
greater than or equal to	≥
harvest per unit effort	HPUE
less than	<
less than or equal to	≤
logarithm (natural)	ln
logarithm (base 10)	log
logarithm (specify base)	$\log_2$, etc.
minute (angular)	'
not significant	NS
null hypothesis	H_O
percent	%
probability	P
probability of a type I error (rejection of the null hypothesis when true)	α
probability of a type II error (acceptance of the null hypothesis when false)	β
second (angular)	"
standard deviation	SD
standard error	SE
variance	
population	Var
sample	var

FISHERY DATA REPORT NO. 04-05

NOME RIVER ARCTIC GRAYLING RESTORATION, SEWARD PENINSULA, ALASKA 2002 AND 2003

by
Alfred L. DeCicco
Division of Sport Fish, Fairbanks

Alaska Department of Fish and Game
Division of Sport Fish, Research and Technical Services
333 Raspberry Road, Anchorage, Alaska, 99518-1599

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Alfred L. DeCicco
Alaska Department of Fish and Game, Division of Sport Fish, Region III,
1300 College Road, Fairbanks, AK 99701-1599,USA

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ABSTRACT

During July 2002, 4,800 Arctic grayling fry were captured from the Nome River and reared in net pens and a tank with circulating water. Upon removal from rearing facilities in September 2002, survival was about 50% in all fed treatments, and about 5% in the unfed treatment. Half the survivors were marked with fin clips and released into the Nome River. The remaining survivors were released into the Banner Creek Pond where over winter survival was poor (4%). In June 2003, 82 age-1 Arctic grayling were captured from the Banner Creek Pond, marked with fin clips and released into the Nome River. In July 2003, 3,191 Arctic grayling fry were captured from the Nome River and reared in six net pens with supplemental feeding. In September, survivors were marked with fin clips and released into the Nome River. Overall survival was 25% in 2003, about half that observed in 2002.

Key words: Arctic grayling, *Thymallus arcticus*, net pen rearing, length composition, growth, Seward Peninsula, Nome River, experimental restoration.

INTRODUCTION

The Seward Peninsula-Norton Sound area of western Alaska supports the second largest amount of recreational fishing effort in the Arctic-Yukon-Kuskokwim (AYK) region. Over the past 10 years, annual estimated sport fishing effort has declined from over 23,000 angler-days in 1991 to 11,000 angler-days in 2001, with an annual average of 17,000 angler-days (Table 1). Reported sport fish harvests consisted primarily of Dolly Varden *Salvelinus malma*, Arctic grayling *Thymallus arcticus*, pink, coho, chum and chinook salmon *Oncorhynchus*, northern pike *Esox lucius*, whitefish *Coregonus*, and burbot *Lota lota*. From 1980 through 1991, Arctic grayling comprised an average of 15% of the harvest of these species, but dropped to an average of 6.6% over the past five years while comprising an average of 24% of the catch (Table 1). The annual harvest was about 1,350 Arctic grayling from 1992 through 1997, however it dropped to about 300 fish in 1998 in spite of a relatively high catch of over 12,000 fish. During 1999-2001, Arctic grayling harvest averaged about 1,250 fish.

The Seward Peninsula is the only area in Alaska outside of Bristol Bay that regularly produces trophy-sized Arctic grayling. Since 1983, 25% of the Arctic grayling registered in the Alaska Department of Fish and Game (ADF&G) Trophy Fish Program have come from the Seward Peninsula (ADF&G *Unpublished*-a).

The Nome River has its headwaters on the eastern edge of the Kigluaik Mountains; it is approximately 70 km long and flows south, entering Norton Sound approximately 5.6 km east of Nome (Figure 1). The river is accessible from the Nome-Taylor highway that parallels much of its length. The Nome River, until recently, has sustained more angler effort than any other stream on the Seward Peninsula (Mills 1984-1994), but currently ranks second. Estimated Arctic grayling harvests in the Nome River ranged from 376 to 528 in the mid 1980s, however annual harvests declined to less than 200 fish in the early 1990s (Table 2).

The Nome River has supported popular sport fisheries for Dolly Varden, and coho and pink salmon, however, salmon fishing has been restricted over the past 10 years because of low returns, and the river was closed to all fishing in 2003. The river has good access for most of its length and has the potential of maintaining higher levels of sport fishing effort because of its proximity to Nome. The Arctic grayling population in the Nome River is currently at a low level of abundance. Stock assessment of the Arctic grayling population in the Nome River during 1992 estimated that there were approximately 725 Arctic grayling > 269 mm FL residing in the river (DeCicco 1993). Based on this assessment, the river was closed to fishing for Arctic

Table 1.–Estimated sport fish harvests[a] and catches[b] for Seward Peninsula and Norton Sound streams, 1980-2001.

	Angler	All Salmon		Dolly Varden		Arctic Grayling		Northern Pike		Burbot		Whitefish	
Year	Days	Harvest	Catch	Harvest	Catch	Harvest	Catch	Harvest	Catch	Harvest	Catch	Harvest	Catch
1980	7,968	10,840		5,811		1,635		284		0		353	
1981	10,879	6,564		3,981		2,104		303		0		123	
1982	13,198	19,757		6,498		6,225		210		0		597	
1983	16,944	11,135		9,853		8,241		798		0		148	
1984	17,436	17,983		4,507		2,349		208		13		39	
1985	19,919	3,610		5,834		4,501		56		175		70	
1986	18,107	9,913		5,721		4,042		699		0		510	
1987	20,413	5,976		5,506		4,600		906		0		272	
1988	20,278	10,715		4,855		4,928		564		36		673	
1989	17,692	9,587		7,058		4,205		648		10		453	
1990	21,799	12,439	27,062	3,948	9,549	1,378	6,119	1,957	4,145	33	33	299	315
1991	23,622	9,594	16,193	10,365	25,425	5,121	23,160	1,429	4,257	116	116	1,357	1,409
1992	22,684	11,932	37,464	2,382	6,012	492	5,772	479	3,742	0	0	46	165
1993	18,930	7,329	17,946	5,907	22,166	1,584	13,223	537	2,117	96	107	95	196
1994	18,922	13,752	25,540	3,071	7,344	1,331	7,081	376	1,731	0	0	67	172
1995	19,647	5,569	14,763	2,908	7,921	1,037	5,788	215	1,856	45	56	247	321
1996	13,783	14,685	35,875	4,285	8,427	1,485	10,406	728	3,239	179	179	64	128
1997	13,850	7,265	22,092	4,467	17,998	1,261	20,187	363	2,188	148	290	212	598
1998	13,616	12,668	42,695	2,240	5,711	298	12,408	75	452	84	93	0	288
1999	15,006	9,462	21,780	6,708	21,428	1,600	16,132	355	2,217	97	109	9	94
2000	18,559	12,358	34,269	7,952	16,348	1,203	11,069	420	1,317	388	399	920	1,173
2001	10,955	7,244	20,470	3,174	7,395	994	9,467	349	3,276	50	50	814	1,108
2002	18,325	10,134	27,863	2,252	7,877	1,565	12,757	326	495	0	0	206	483
							Averages						
1997-2001	14,397	9,799	28,261	4,908	13,776	1,071	13,853	312	1,890	153	188	391	652
1992-2001	16,595	10,226	27,289	4,309	12,075	1,129	11,153	390	2,214	109	128	247	424

[a] Data from Howe et al. 1995, 1996, 2001 a-d, Jennings et al. (*In prep*) Mills 1981-1994, Walker et al. 2003.

[b] Catch data not available prior to 1990.

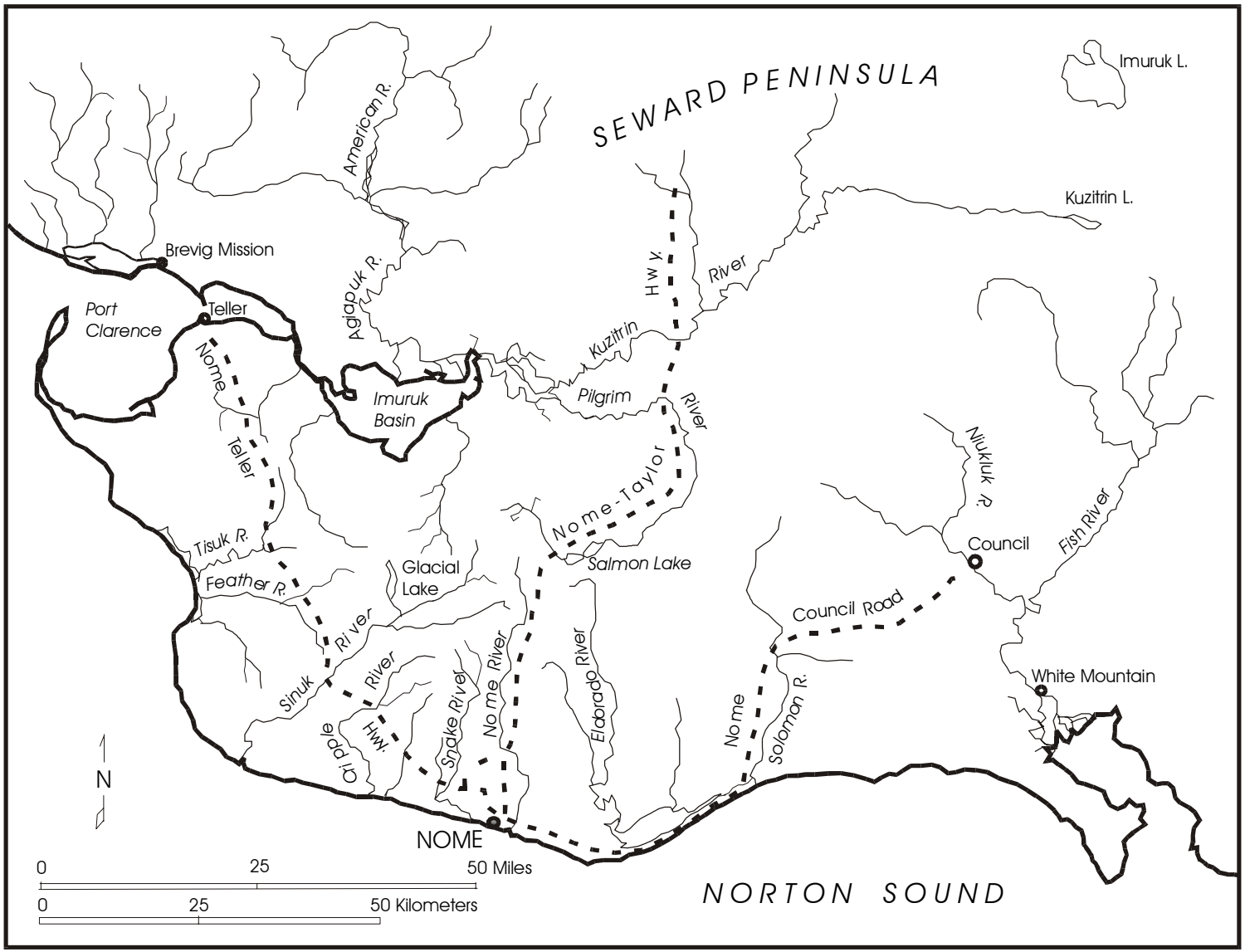


Figure 1.–The southern Seward Peninsula.

Table 2.–Arctic grayling catch, effort and harvest in the Nome River, 1983-2002.

Year	Number Anglers	Days Fished	Grayling Harvest	Grayling Catch
1983	0	3,908	464	nd
1984	1,288	5,714	376	nd
1985	1,220	6,514	528	nd
1986	1,087	6,023	491	nd
1987	674	1,865	344	nd
1988	1,733	6,058	946	nd
1989	1,231	6,569	2,032	nd
1990	1,625	7,194	33	613
1991	1,277	4,646	186	1,363
1992	1,433	6,455	0	90
1993	1,181	3,633	0	569
1994	1,025	5,116	16	1,111
1995	859	3,044	0	571
1996	947	2,920	0	497
1997	691	1,914	0	569
1998	636	1,371	0	207
1999	564	1,463	0	300
2000	450	1,455	0	10
2001	312	1,045	0	60
2002	606	1,901	0	735
		Averages		
1992-2001	810	2,842	2	398
1997-2001	531	1,450	0	229

grayling by emergency order in 1992, and has remained closed. In 1997, the same 42 km section of the Nome River was assessed and the abundance of Arctic grayling was found to be of similar (abundance = 687 fish >249 mm; DeCicco 1998). The only change in the population was that the modal size had increased (Figure 2). In December 1997 the Alaska Board of Fisheries (BOF) adopted a proposal to close the Nome River to sport fishing for Arctic grayling. Abundance was again estimated in 2000 and the population had not shown signs of recovery (abundance = 551 fish >299 mm; DeCicco 2002). Based on this information, the BOF closed the Nome River to subsistence fishing for Arctic grayling in January 2001.

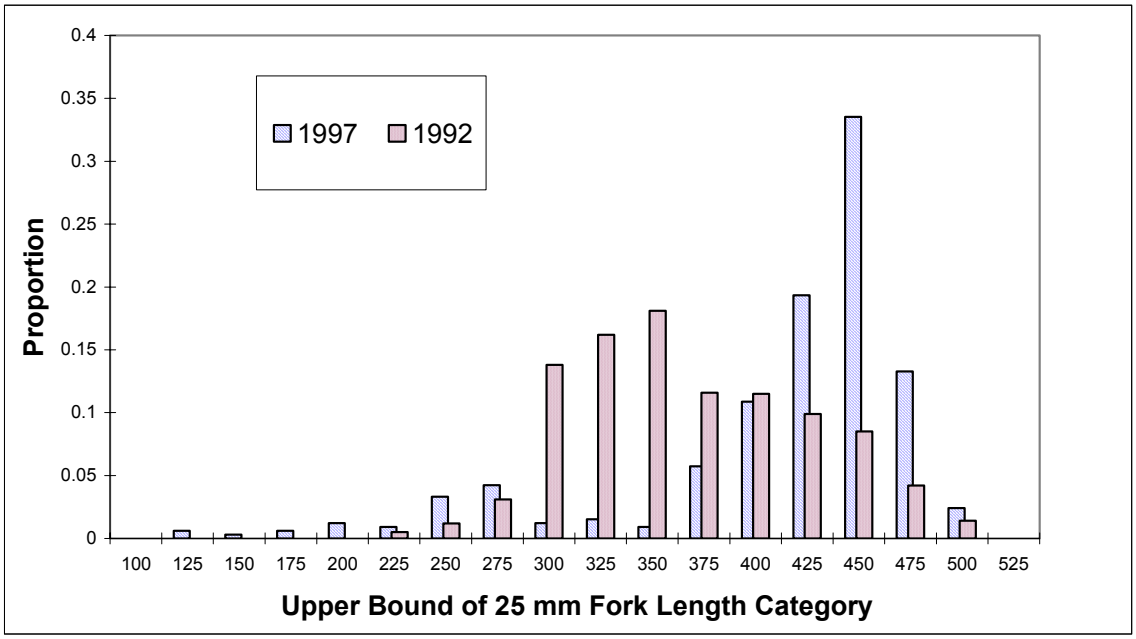


Figure 2.–Length distribution of Nome River Arctic grayling in 1992 and 1997.

Adult Arctic grayling production is likely not limited by nutrient input. Large quantities of decomposing salmon carcasses have been present in the river during alternate years of high pink salmon abundance. Input of nutrients from carcasses has been correlated to productivity (Kline et al. 1997). Young-of-the-year (YOY) Arctic grayling were observed in small schools along the margins of the lower reaches of the river during July 1997 - 1999. It is assumed that these young fish move downstream with the current, particularly in years with high stream flows, and may be carried into the coastal lagoon or even into the Bering Sea where they are lost to predation or osmoregulatory stress. Arctic grayling production in the Nome River may also be limited by insufficient rearing habitat. Off-channel sloughs in the lower river have become disconnected due to low water levels in recent years thus decreasing the amount of slow-moving water and potential rearing area (R. McLean, Alaska Department Natural Resources, Fairbanks, personal communication). Whatever the reason, it appears that young Arctic grayling are produced during most years, but very few survive to enter the adult population. During sampling in 1997, only 20 fish smaller than 250 mm FL were captured in the Nome River using hook and line and beach seines, and during 2000, none were captured (ADF&G *Unpublished*-b). The

length structure of the population suggests that there is poor survival of young fish, hence very low recruitment to the population.

Jennings (1983) reported that survival of Arctic grayling sac-fry stocked into small sub-Arctic lakes was low (0.01 – 0.10). He found that mortality was "knife-edged" with most mortality occurring within 3-4 days of stocking, and suggested that this resulted from predation by invertebrates because the sac-fry were weak swimmers and tended to rest on the lake bottom upon introduction. Hemming (1995) performed an experiment in which he took YOY Arctic grayling from the Kuparuk River and placed them in a small tundra pond for the summer. Upon removal from the pond, he found rapid growth and high survival (0.95). Since fish were removed from the lake using fyke traps, survival may actually have been higher.

This project was undertaken in an attempt to boost recruitment of young fish into the Nome River Arctic grayling population, and was the second attempt at restoration of the Arctic grayling population in the Nome River (Figure 3) by enhancing over-winter survival of YOY Arctic grayling, thereby increasing recruitment to the population. It also served to develop methods that may be used in future rehabilitation efforts. In 1998, 670 YOY Arctic grayling were transferred to the gravel pit at Banner Creek (Figure 4) in order to determine if pond reared fry might be raised successfully. A barrier of 3.2 mm Vexar mesh was erected to isolate the northwest arm of the pond for rearing. To reduce the potential for both predation and competition, other fish present in the pit were removed with baited minnow traps over a 10-day period. One nine-spine stickleback *Pungitius pungitius*, three Dolly Varden, 48 slimy sculpin *Cottus cognatus*, and 367 juvenile coho salmon were captured from the experimental arm and released into the adjacent arm of the pond.

By the spring of 1999, only one Arctic grayling fry survived to be captured. Subsequent data from this pit indicated that 1999-2000 winter temperatures were sustained at 0^{o}C for many days in its deepest area (ADF&G *Unpublished*-b). If similar conditions existed during the previous winter, then this was likely the cause of the low observed survival.

Dissolved oxygen level was measured at 11.6 mg/l from a water sample taken from the ice covered gravel pit on November 6, 1998. However, another pond that appeared to be more suitable was found nearby. Dissolved oxygen (DO) beneath 2 m of ice on April 13, 2000 was measured at 11mg/l in the unsuccessful gravel pit with a water temperature of 0.5^{o} C. On the same day, 12.3 mg/l DO was found in the nearby pond with a water temperature of 1.0^{o} C.

The new pond, henceforth referred to as the Banner Creek Pond (Appendix A1), was the location of this study to determine if increasing recruitment to the Arctic grayling population in the Nome River by enhancing YOY survival was a feasible approach to restoring the population.

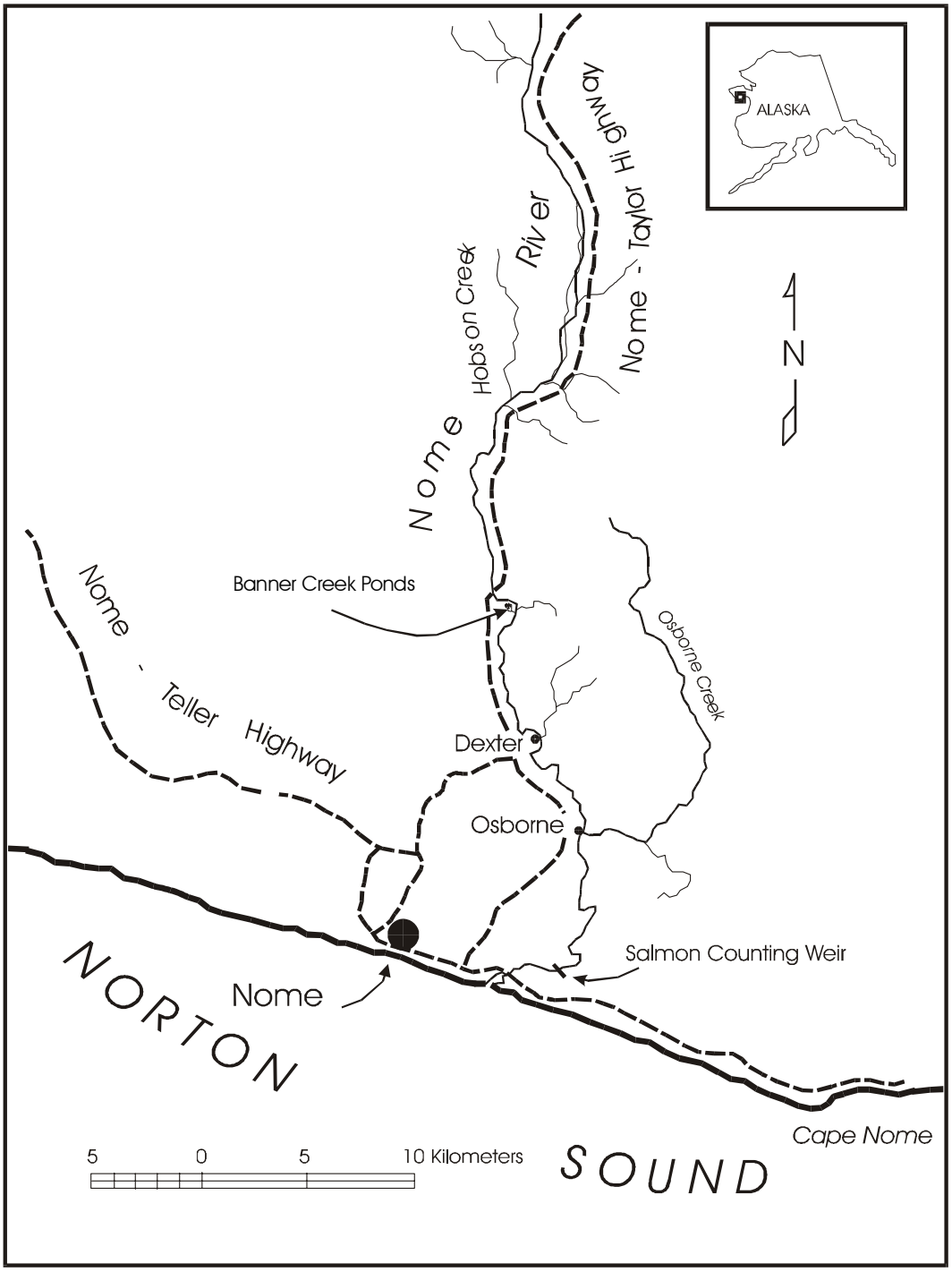


Figure 3.–The Nome River drainage showing the location of the Banner Creek Ponds.

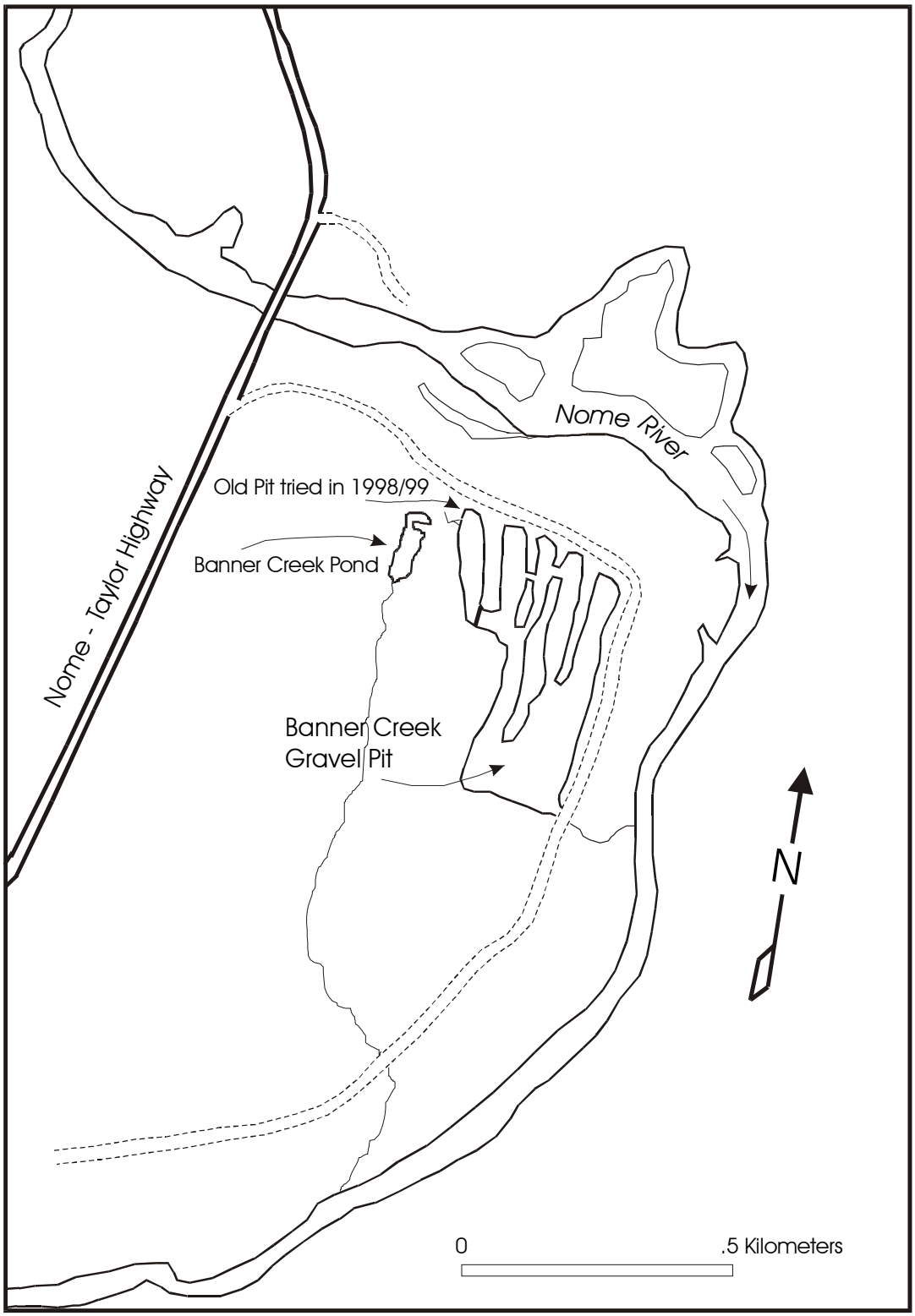


Figure 4.–The Banner Creek gravel pit and Banner Creek Pond.

OBJECTIVES

Project objectives for Nome River Arctic grayling restoration in 2002 were to:

1. capture and rear up to 4,800 Nome River stock Arctic grayling for release into the Nome River;
2. measure survival rate and estimate change in mean length and weight of fry reared using up to 4 different treatments during the summer rearing period (July-September);
3. estimate survival rate and change in mean length and weight of fry reared using up to 5 different treatments during the overwintering period (September – June) in the Banner Creek Pond;
4. estimate the mean length of fry in each treatment group at the time of the September release into the Banner Creek Pond and the June recapture, so that the estimates are within 2 mm of the true mean 95% of the time;
5. estimate the mean weight of fry in each treatment group at the time of the September release into the Banner Creek Pond and the June recapture so that the estimates are within 0.5 g of the true mean 95% of the time; and,
6. estimate the contribution of these fish to the population of Arctic grayling in the Nome River after three or four years.

Objectives for 2003 were to:

1. capture and rear up to 6,000 Nome River stock Arctic grayling for release into the Nome River;
2. measure survival rate and estimate change in mean length and weight of fry reared in holding pens (600/pen) during the summer rearing period (July–September);
3. estimate survival rate and change in mean length and weight of fry reared during the overwintering period (September–June) in the Banner Creek Pond;
4. estimate the mean length at the time of the September release into the Banner Creek Pond and the June recapture so that the estimates are within 2 mm of the true mean 95% of the time; and,
5. estimate the mean weight of fry at the time of the September release into the Banner Creek Pond and the June recapture so that the estimates are within 0.5 g of the true mean 95% of the time.

METHODS

YOY Arctic grayling were captured from the Nome River in the area just upstream from Osborne Creek (Figure 3) using a 30 m X 1 m beach seine with 4 mm mesh on 26-28 July 2002. The area (approximately 1.5 km) was seined in a downstream direction until approximately 5,000 fry were captured. Captured fry were placed in a plastic tub filled with water from the river and transported to the Banner Creek pond at the end of each day. Fry were counted, and a

sample (n=160) was measured and weighed (n=46 10-fish groups) before release into either a 1 m X 2 m X 1 m holding pen or 1.2 m circular tank.

In 2002, YOY Arctic grayling were reared in the Banner Creek Pond in five treatment groups: in net-mesh holding pens (three groups), a circular tank (one group) and free swimming in the pond (one group).

Pen treatments consisted of two densities, 300 fish/pen, and 600 fish/pen (Table 3). Fry in the treatments requiring food were fed daily using a spring-motorized fish feeder at a rate of approximately 2% of total fish weight/day. Three pen treatments with a density of 300 fish/pen were reared without supplementary feeding. The tank treatment consisted of 660 fish that were fed at the same rate as the pen treatments. A control group of 600 fish was released directly into the pond. Each treatment group received a specific fin clip when fish were released into the pond or river except the control group that did not receive a fin clip until they were released into the river in the spring of 2003. In 2002, Arctic grayling fry were distributed daily into treatment groups as they were captured.

Table 3.–Treatment groups and fin clips used in the 2002 Arctic grayling rearing experiment.

Treatment	Holding Device	Number	Fin Clip	Fed or Unfed
1	1.2 m Circular Tank	600	Left Pectoral	Fed
2	1 m X 2 m X 1 m Holding Pen	300	Right Pectoral	Unfed
3	1 m X 2 m X 1 m Holding Pen	300	Right Pectoral	Unfed
4	1 m X 2 m X 1 m Holding Pen	300	Right Pectoral	Unfed
5	1 m X 2 m X 1 m Holding Pen	300	Adipose	Fed
6	1 m X 2 m X 1 m Holding Pen	300	Adipose	Fed
7	1 m X 2 m X 1 m Holding Pen	300	Adipose	Fed
8	1 m X 2 m X 1 m Holding Pen	600	Right Ventral	Fed
9	1 m X 2 m X 1 m Holding Pen	600	Right Ventral	Fed
10	1 m X 2 m X 1 m Holding Pen	600	Right Ventral	Fed
11	Banner Creek Pond	600	None	Unfed

In 2003, all captured fry were reared in six pens (same as used in 2002) and all were fed. Between 500 and 600 fry were initially placed in each of the pens.

FEEDING

Pens for the "fed" treatment groups were equipped with 24-hr spring-motorized belt feeders and supplied with food daily. In order to achieve a rate of approximately 2% of total fish weight/day (J. Milton, Ft. Richardson Hatchery, personal communication), a random sample of 10 fish from each treatment group was weighed at the beginning of each week. A conversion chart based on the length-weight relationship of grayling fry and the known number of fish in each tank or pen

was used to calculate the appropriate amount of food/day for the following feeding period (Appendix B1). Fish were fed Moore-Clark Nutra Plus[1] food. Nutra Plus 0 was fed until fish averaged 0.8 g, Nutra Plus 1 until they reached an average weight of 1.5 g, and Nutra Plus after they reached 1.5 g.

ASSESSMENT

All fish were removed from pens or tanks on September 19-21, 2002 and given a fin clip to identify them by treatment group. Half the fish from each treatment group were released into the Nome River at that time and the remainder of each treatment group was released into the Banner Creek Pond. A sample of fish from each treatment was measured individually and weighed in groups of 10 (several groups per treatment) prior to release into the Nome River or the Banner Creek pond in order to estimate average weight. In June 2003, fish were captured from the Banner Creek Pond, weighed, measured, given a left ventral fin clip and then released into the Nome River. A minimum estimate of winter survival in the Banner Creek Pond by treatment group was calculated based on the number of age-1 Arctic grayling captured in the spring of 2003 with fin-clips identifying them to treatment group compared to the number in each group placed in the pond in September 2002. If survival of any treatment was 20% or greater this aspect of the project would be deemed a success (C. Skaugstad, Alaska Department of Fish and Game, Fairbanks, personal communication) and plans for additional restoration efforts were to proceed. The treatment(s) with the highest survival and the lowest cost will be selected for future restoration efforts. If winter survival of all groups released into the Banner Creek Pond was less than 20%, then future releases would likely take place in the fall after summer pen-rearing. If survival was 20% or greater, fry would be reared throughout the winter in the pond and released the following spring. During the spring of 2003 it was found that survival was <20% so all fry reared in 2003 were released directly into the Nome River during September 2003.

MEAN LENGTH AND WEIGHT

Mean length of Arctic grayling at initial capture was determined by individually measuring those fish that died during seining and handling at capture. Mean weight at capture was determined by weighing the entire sample of dead fry and dividing by the number of fish in the sample. Individual weights were also taken, but due to the sensitivity of the scale, summing their weights gave a larger total weight than weighing the entire sample, and biased the mean high. The weight by treatment group, after pen rearing, was calculated as the arithmetic mean of multiple random samples of 10 fish taken from each treatment group at the time of transfer from the pens to the pond or from the pens to the Nome River. The same methods were used to estimate weight and length of fish captured from the pond in the June 2003 and September 2003.

Length distributions of fish by pen in 2002 were compared using a series of K-sample Anderson-Darling (AD) tests (Scholz and Stephens 1987). Pen aggregates by treatment group were compared using a One-Way ANOVA (Elliott 1977). The K-sample AD was also used to compare the length distributions of fish removed from holding pens in the fall of 2003.

[1] Product names used in this report are included for scientific completeness, but do not constitute product endorsement.

RESULTS

The initial capture event on the Nome River was successful with 4,860 Arctic grayling fry seined and transferred to pens on 26-28 July 2002. Fry were moved to holding facilities in the Banner Creek Pond and released into the pens after a sample was measured and weighed. In 2002, the average length of fry at capture was 42.3 mm (SD = 3.2; n = 160). Lengths ranged from 34 mm to 48 mm. The overall mean weight was 0.67 g (n = 46 10-fish samples, SD = 0.16).

Fish were removed from pens and released into the Banner Creek Pond and into the Nome River on September 19-21, 2002. A sample of fish from each treatment group was measured and weighed upon release (Tables 4 and 5). The size ranges of fish in all fed treatments were similar and larger than the few fish that survived in the unfed treatments (Figures 5 and 6). Overall survival was about 50% in the fed treatments and only 5% in the unfed treatments. Upon the transfer of the fish it was discovered that one of the pens with a fed treatment of 600 fish had a 3 cm hole, and only 36 fish remained. It is likely that most escaped into the pond, and since these fish were unmarked, they were considered an addition to the 600 fish control that was released directly into the pond in July.

LENGTH DISTRIBUTIONS, MEAN WEIGHT AND SURVIVAL, 2002

Lengths were determined for samples of fish from each treatment group at transfer from the rearing pens to the Banner Creek Pond or the Nome River on 19-21 September 2002. Length ranges were similar among all fed treatments (Figure 5), however, K-sample Anderson Darling tests found significant differences among length distributions in all pens (A2kn = 68.6, $P < 0.01$). Subsequent AD tests indicated differences in length distributions between pens within treatments as well as differences across treatments.

Table 4.–Length statistics of Arctic grayling fry released from tank and pens, 19-21 September 2002. Treatments: 1 – 600 fry in circular tank, fed; 2, 3, 4 – 300 fry/pen, unfed; 5, 6, 7 – 300 fry/pen, fed; 8, 9, 10 – 600 fry/pen, fed.

	Treatment									
	1	2	3	4	5	6	7	8	9	10
Number measured	136	5	7	29	128	88	115	36	132	168
Mean Length (mm)	54.1	46.2	46.3	43.6	58.0	53.90	55.5	53.8	56.4	55.5
Standard Error	0. 7	0.7	0.9	0.4	0.7	0.9	0.7	1.5	0.7	0.6
Standard Deviation	7.8	1.5	2.3	1.9	8.0	8.4	7.8	8.8	7.8	7.1
Sample Variance	61.0	2.2	5.2	3.6	63.2	69.8	60.6	77.7	60.3	49.9
Minimum	40	44	43	38	35	39	40	40	41	36
Maximum	74	48	49	47	74	76	70	71	72	75

Table 5.–Arctic grayling summary by treatment group, 2002.

Treatment	No. In	No. Out	Mean Length In (mm)	Mean Length Out (mm)	Mean Wt. In (g)	Mean Wt. Out (g)	Survival to Transfer
Circular tank	660	301	42.3	54.1	0.67	2.00	0.46
Pen 1 - unfed	300	5	42.3	46.2	0.67	0.90	0.02
Pen 2 – unfed	300	8	42.3	46.3	0.67	0.63	0.03
Pen 3 – unfed	300	29	42.3	43.6	0.67	0.73	0.10
Pen 4 – fed	300	160	42.3	58.0	0.67	1.81	0.53
Pen 5 – fed	300	172	42.3	53.6	0.67	2.14	0.57
Pen 6 – fed	300	150	42.3	55.0	0.67	1.98	0.50
Pen 7- fed	600	36	42.3	53.8	0.67	2.15	0.06
Pen 8 – fed	600	280	42.3	56.4	0.67	1.94	0.47
Pen 9 – fed	600	334	42.3	55.5	0.67	1.95	0.56
Control in pond	600	unknown	42.3	Unknown	0.67	unknown	unknown
Total	4,860	1,475	42.3	55.0	0.67	1.94	0.15
Treatment Summary							
Circular tank	660	301	42.3	54.1	0.67	2.00	0.46
Pen, unfed/300	900	42	42.3	44.4	0.67	0.73	0.05
Pen, fed/300	900	482	42.3	55.5	0.67	1.98	0.54
Pen, fed/600 [a]	1,200	614	42.3	55.9	0.67	1.95	0.51

[a] Does not include data from pen with hole

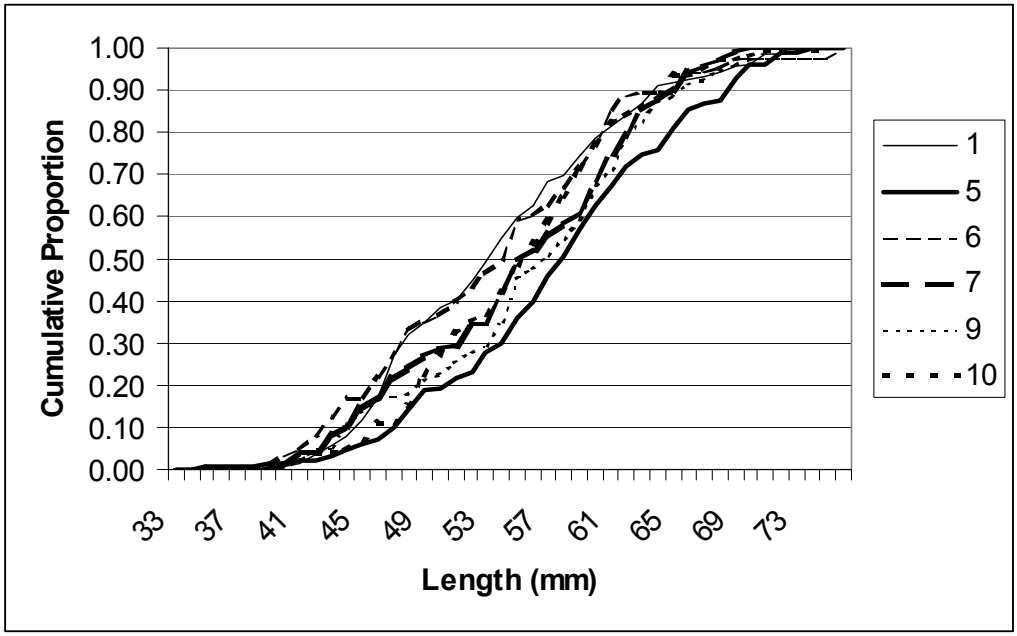


Figure 5.–Cumulative length frequency of Arctic grayling fry released from tank and fed pens, 19-21 September 2002. Treatments: 1 – 600 fry in circular tank, fed; 5, 6, 7 – 300 fry/pen, fed; 9, 10 – 600 fry/pen, fed.

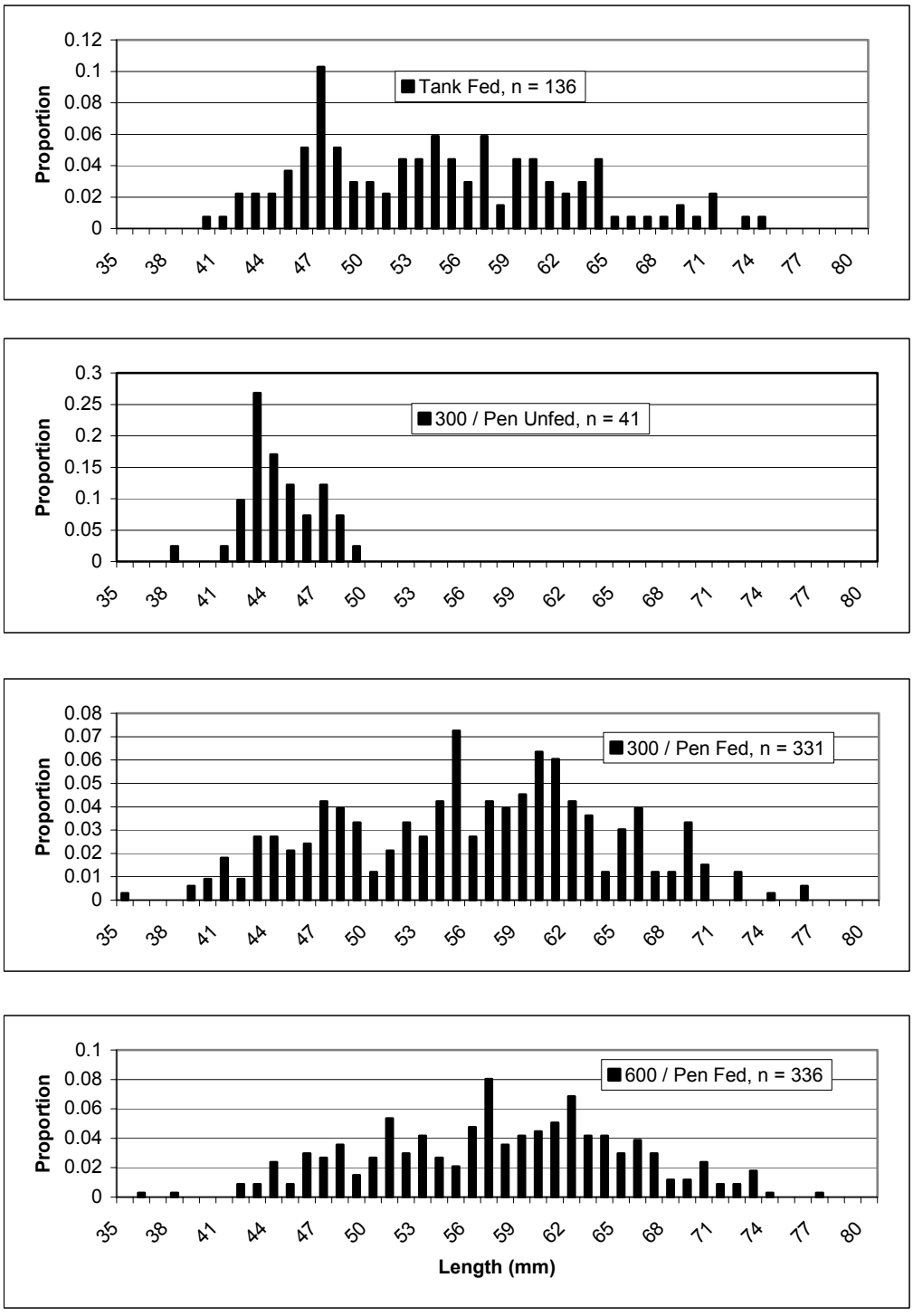


Figure 6.–Length distribution of Arctic grayling fry released from treatment groups, 19-21 September 2002.

The length distributions of fish in the unfed pens, as expected, were smaller and survival was poor. Overall, fish in the fed treatments ranged from 35 to 76 mm in length, and fish in the unfed treatments ranged from 38 to 49 mm in length.

In 2002, fry grew from a mean of 42.3 mm (n = 160, SD = 3.24 mm) in June to a mean length of 55.6 mm (n=803, SD = 7.87 mm) in September in fed treatments and a mean length of 44.37 mm (n = 41, SD = 2.25 mm) in the unfed pens. The overall range of length increase from all treatments is depicted in Figure 7.

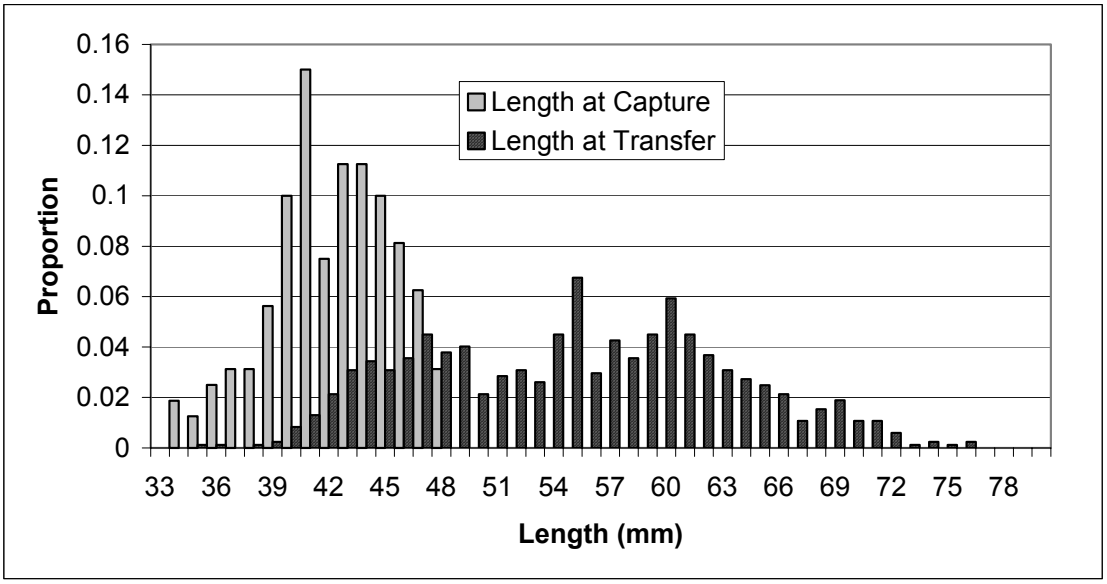


Figure 7.–Length distributions of Arctic grayling fry at capture, and after pen rearing in the Banner Creek Pond in 2002.

Analysis of Variance (Elliott 1977) was used to test for differences between treatments, by analyzing median lengths for each pen. No differences were found between fed treatments ($F_{2, 4}$ = 0.45; P = 0.67), however significant differences between treatments were detected when the unfed treatment was included ($F_{3, 6}$ = 16.76; P < 0.01). Analysis of mean lengths for each pen yielded similar results.

Mean weight increased from 0.67 g (n = 46; 10 fish groups; SD = 0.16 g) in June to 2.03 g (n = 61; 10 fish groups; SD = 0.27 g) in September in fed treatments, and 0.73 g (n = 42 fish) in unfed groups.

SPRING RECAPTURE 2003

During June 2003, Arctic grayling were captured from the Banner Creek Pond using hoop traps with wings and beach seines and released into the Nome River. Only 82 Arctic grayling were recaptured in 10 days of trapping and seining. Recaptured fish ranged in length from 58 mm to 87 mm (Figure 8) with a mean length of 72.9 mm (SD = 6.19) and an average weight of 4.2 g. Overwinter survival by treatment group ranged from 2.4% for the unfed treatment to about 5% for all the fed treatments (Table 6). Over winter survival of the control group could not be

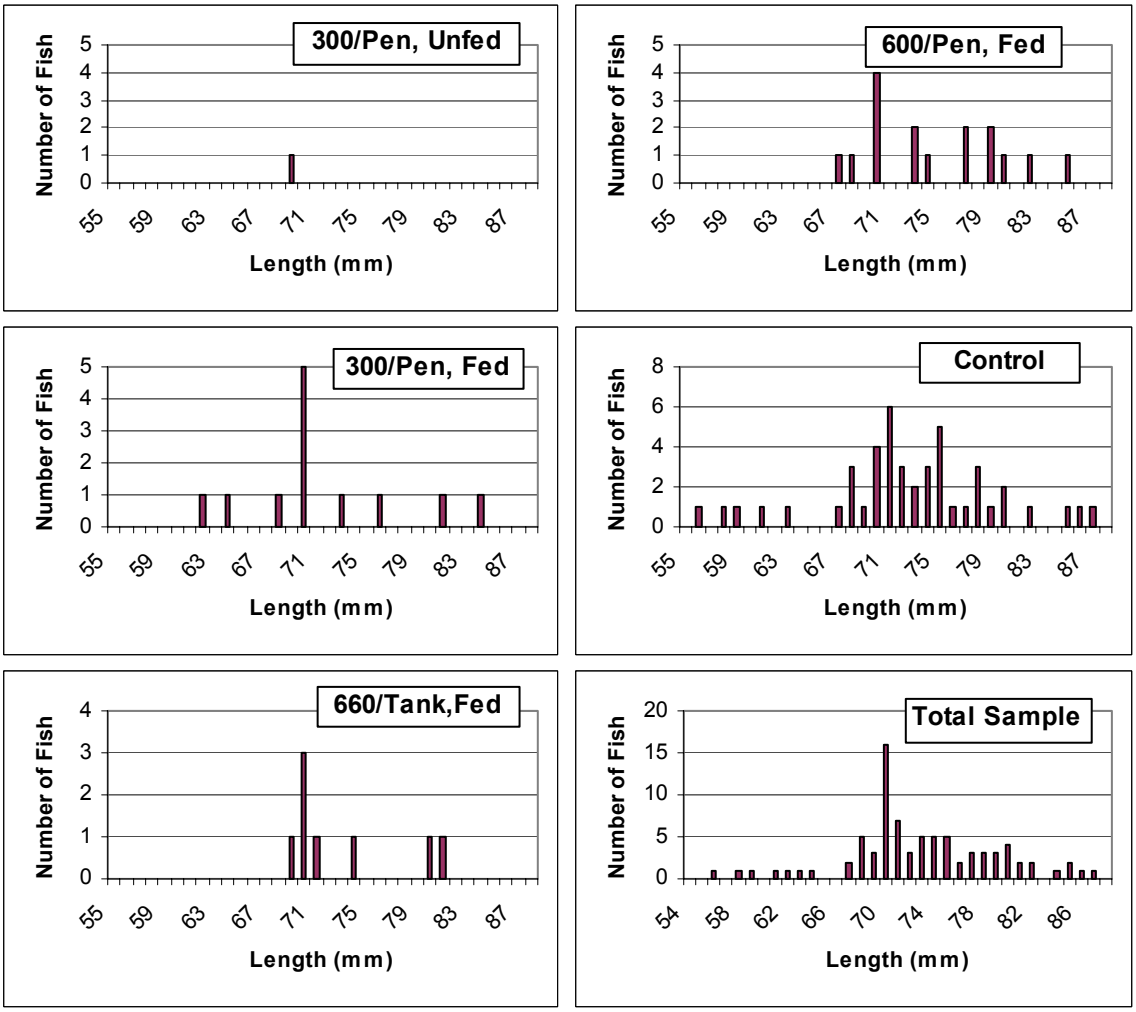


Figure 8.–Length composition of Arctic grayling captured in Banner Creek Pond and released into the Nome River, spring 2003.

Table 6.–Survival of Arctic grayling fry reared in Banner Creek Pond 2002-2003. Note: Fall 2002 control is an estimate based on 50% survival found in treatment groups.

Treatment	Fin Clip	Spring 2002 Initial Number	Survival Spring-Fall	Fall 2002 No. into Pond	Spring 2003 No. Recaptured	Survival Fall-Spring	Survival Spring-Spring[a]
660/tank-fed	LP	660	0.46	150	8	0.05	0.02
600/pen-fed	RV	1,236	0.53	325	16	0.05	0.03
300/pen-fed	Ad	900	0.54	241	12	0.05	0.03
300/pen-unfed	RP	900	0.05	42	1	0.02	<0.01
control+escaped	None	1,164		582	45		0.04

[a] Spring to spring survival = spring to fall survival X fall to spring survival.

calculated directly because the number of fish present during the fall of 2002 was unknown. However, overall survival from spring 2002 to spring 2003, of the control group including fish that escaped one pen, was about 4% higher than any of the other treatments. All recaptured fish were given a left ventral fin clip and released into the Nome River on June 20, 2003. The mean length of 10 wild age-1 Arctic grayling captured in the Nome River on June 17, 2003 was 81.4 mm (SD = 8.25). This Nome River cohort was sampled two additional times. On September 21, 2002 the mean length of age-0 Arctic grayling was 74.4 mm (n = 13; SD = 3.82) and on July 24, 2003, the mean length of age-1 Arctic grayling was 116.2 mm (n = 45; SD = 7.98).

LENGTH DISTRIBUTIONS, MEAN WEIGHT AND SURVIVAL, 2003

A total of 3,191 YOY Arctic grayling were captured from the Nome River on July 24-26, 2003 and placed in six holding pens in the Banner Creek Pond at a density of approximately 500/pen. The same feeding regime used in 2002 was used in 2003. A random sample of fish (n = 78) was measured resulting in a mean length of 39.5 mm for the July sample transferred from the river to the pens. Groups of 10 fish were weighed to obtain a mean weight. A total of 74 groups were weighed resulting in a mean weight of 0.65 g per fish at capture. The group weights ranged from 4.6 g to 10 g with a mean of 6.5 g (SD = 1.0 g).

Surviving pen reared Arctic grayling (n = 794) were taken from the holding pens and released into the Nome River on 26 September 2003. At transfer, the mean length of the fish was 59.9 mm (SD = 12.9 mm), and the mean weight (determined by group weight) was 2.2 g. Survival in 2003 was 25%, approximately half that found in 2002 (Table 7).

Table 7.–Summer survival of Arctic grayling released into the Nome River in fall 2003 by pen.

Arctic Grayling Fry 2003	**Pen 1**	**Pen 2**	**Pen 3**	**Pen 4**	**Pen 5**	**Pen 6**	**Total**
Number placed in pen	**500**	**500**	**574**	**500**	**517**	**600**	**3,191**
Number removed	**105**	**132**	**171**	**121**	**128**	**137**	**794**
Percent survival	**21**	**26**	**30**	**24**	**25**	**23**	**25**

The mean length of fish by pen varied from 56.5 mm (SD = 11.7) in pen 6 to 65.7 mm (SD = 13.3) in pen 1 (Table 8). The length ranges of Arctic grayling fry were similar among most pens

in September 2003 (Figure 8), however, length distributions varied. For example, higher proportions of larger fish and lower proportions of small fish were evident in pen 1 where survival was poorest and fewer fish were present (Figures 9 and 10).

Table 8.–Mean length of Arctic grayling fry by pen, September 2003.

Lengths (mm)	Pen 1	Pen 2	Pen 3	Pen 4	Pen 5	Pen 6
Sample size	117	132	174	123	129	139
Mean	65.7	60.2	60.6	58.5	58.6	56.5
SD	13.3	13.7	12	13.2	12.2	11.7
Minimum	30	31	32	33	37	27
Maximum	86	89	85	88	88	86

A K-sample Anderson Darling test comparing length distributions from the six pens found that the distributions were significantly different (A2kn = 24.39; P = <0.001). When data from pen 6 were removed (the sample that contributed most to the A2kn value) the five remaining length distributions were still significantly different (A2kn = 8.259, P =0.0015). Removing the sample from pen 1 and duplicating the test resulted in no significant differences among the four remaining length distributions (A2kn = 3.708, P = 0.24). Based on this series of tests, pens 1 and 6 had different length distributions than the remaining four pens (Figure 11).

DISCUSSION

This project has served as a pilot for developing techniques for future restoration work involving Arctic grayling in depressed systems. It met with mixed success. Three components are critical to any future use of these techniques to address restoration of Arctic grayling populations.

First, the ability to collect YOY Arctic grayling from the river was critical to the success of the project. During the two years of this project, there was success in this aspect of the experiment using a small mesh beach seine. Capture in 2002 was exceptionally successful as a result of the large number of fry available, low stream flows and warm water temperatures that provided excellent conditions for rearing fry. Because of these conditions, natural production and survival of Arctic grayling fry in the Nome River was likely near optimal. In 2003, conditions were less than optimal. Fry were available, but in lower density, and more effort was needed to capture fewer fish (3,000 fry in three days of effort). In contrast, 2001 was a cool summer, water temperatures were low, flows were higher than normal, growth rates were lower, and survival was poor. In a day of exploratory seining on the Nome River in 2001, fewer than 50 Arctic grayling could be found at the same date and location where hundreds were easily captured in the preliminary work the previous year, and where thousands were captured in 2002 and 2003. Similar efforts on the Snake River confirmed that few Arctic grayling fry were produced in Nome area streams in 2001.

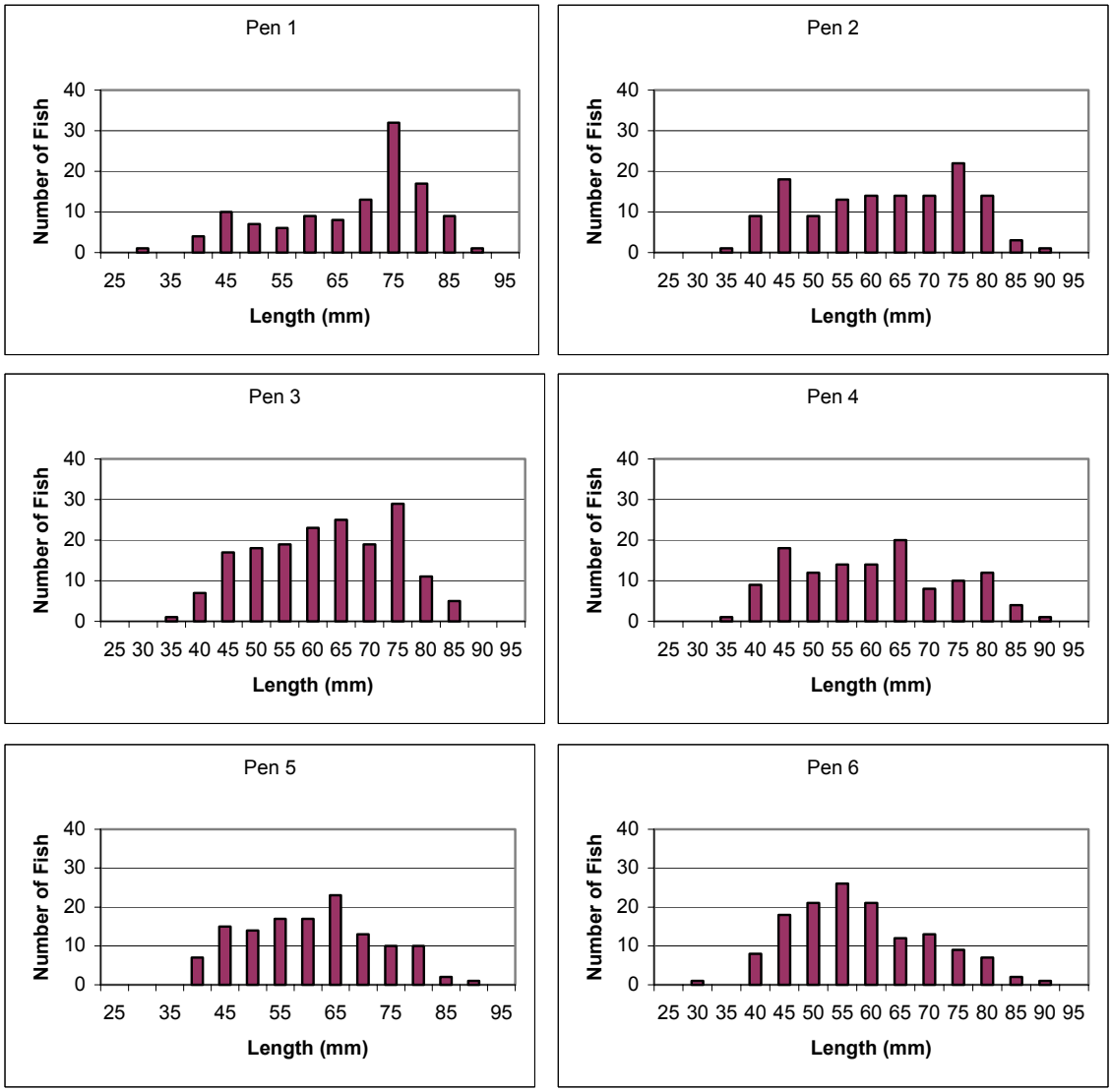


Figure 9.–Length distribution of Arctic grayling fry by pen, September 2003.

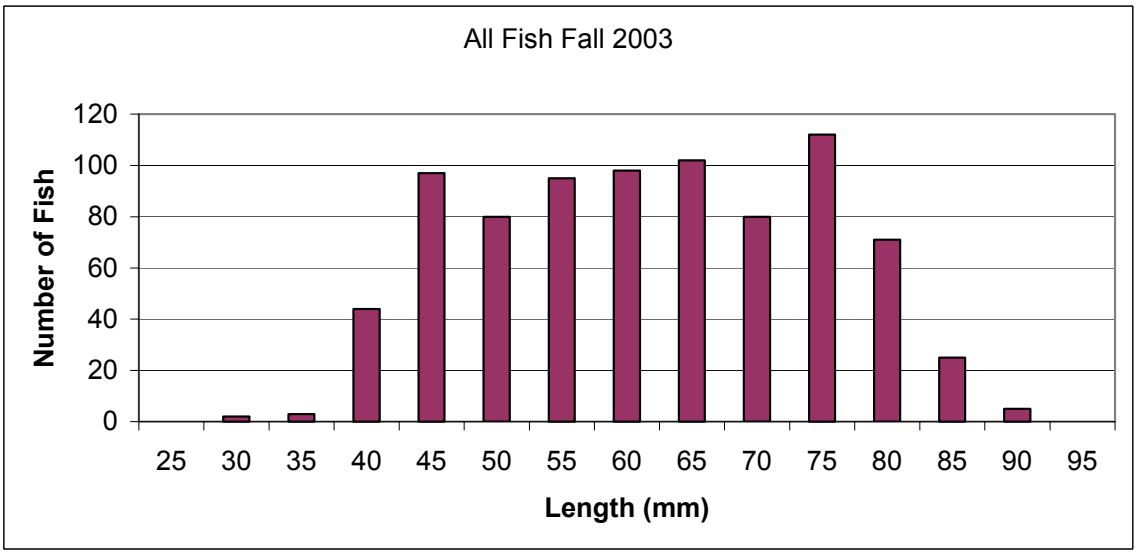


Figure 10.–Length distribution of Arctic grayling transferred to the from pens to the Nome River, September 2003.

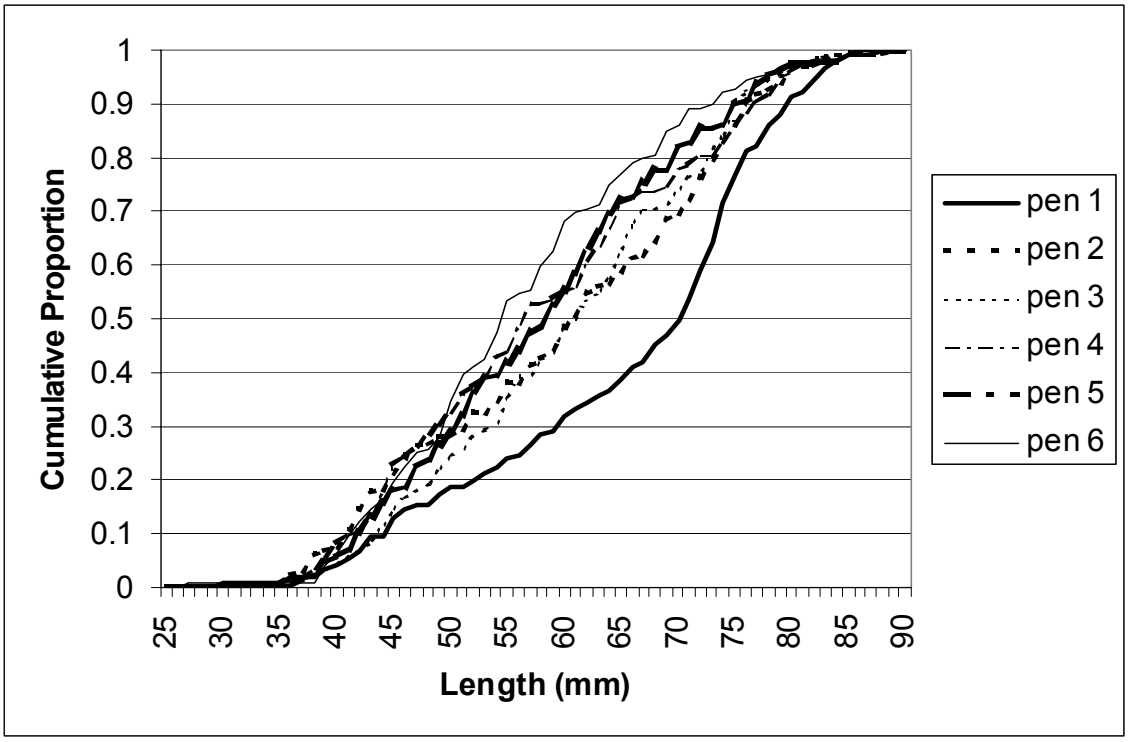


Figure 11.–Cumulative length distribution of Arctic grayling fry by pen, September 2003.

Second, successful pen rearing was also critical to the overall success of the project. In this respect, our experiment was successful. Growth rates were only slightly less than those observed in the Nome River, and survival was about 50% for all treatment groups in 2002. Based on the results from 2002, fish were held in pens in 2003 at a density of about 500 fish per pen and were fed daily. Growth in 2003 was similar to that found in 2002, so this aspect of the experiment was successful and repeatable, but survival was half that found in 2002. I have no explanation for the lower level of survival in 2003, however extremely warm weather for about a week in August 2003 may have contributed to reduced survival. The methods tested in this aspect project may be useful in future rehabilitation efforts.

Third, if a spring release is desired, survival rates over the winter must be adequate to justify the effort involved in pen rearing and recapture of the fry. We considered 20% winter survival as acceptable, however we found that winter survival was very poor, about 4% overall in the winter of 2002/2003. Because of low winter survival in 2002/2003, I elected to release all the fry held in pens in 2003 during September in the hopes that survival will be better in the Nome River than in the pond. The ultimate success of this strategy remains to be evaluated. All released fish have been marked, so evaluation will be possible in the future. If it is found that fish reared for one summer survive and contribute to the population in the river, this may be the most efficient approach to restoring the population in the Nome River or other exploited systems.

Over winter survival was greatest for the control group of fish that were released directly into the pond, however it was still very low (4% from initial capture). If adequate numbers of fry are available, this strategy may be the most desirable, however, spring recapture methodology must be refined to maximize catch rates or another pond with the capability to overwinter fry more successfully must be located.

One rearing method that was not included in this study but may be useful in future rehabilitation efforts is rearing fish for the summer in small tundra ponds. This method was used successfully in one attempt on Alaska's North Slope (Hemming 1995), but was not included in this study because the original intent of this project was to hold fish over the winter and release them the following spring. Overwinter survival was poor, but greatest in the free-swimming control group. Spring to fall survival could not be directly estimated for this group, and may have been equal to or greater than pen reared treatments. Additional options for summer only rearing were not investigated, but tundra pond summer rearing options should be investigated in the future.

ACKNOWLEDGMENTS

I would like to thank Ronda Sparks and Alegra Banducci for their assistance in capturing fry. Paul Thompson fed penned fish daily and assisted during their release. Dan Reed assisted with biometric support and edited this report.

REFERENCES CITED

ADF&G (Alaska Department of Fish and Game). *Unpublished*-a. Trophy fish program history (1967-1995). Alaska Department of Fish and Game, Juneau.

ADF&G (Alaska Department of Fish and Game). *Unpublished*-b. Unpublished data from sampling conducted in the Nome River 1999-2000. Alaska Department of Fish and Game, Fairbanks.

DeCicco, A. L. 1993. Assessment of selected stocks of Arctic grayling in streams of the Seward Peninsula, Alaska, during 1992. Alaska Department of Fish and Game, Fishery Data Series No. 93-36, Anchorage.

REFERENCES CITED (Continued)

DeCicco, A. L. 1998. Assessment of selected stocks of Arctic grayling in streams of the Seward Peninsula, Alaska, during 1997. Alaska Department of Fish and Game, Fishery Data Series No. 98-19, Anchorage.

DeCicco, A. L. 2002. Stock assessment of Arctic grayling in the Nome River and age validation of Arctic grayling in the Eldorado River, Seward Peninsula, Alaska 2000, Alaska Department of Fish and Game, Fishery Data Series No. 02-1, Anchorage.

Elliott, J. M. 1977. Some methods for the statistical analysis of samples of benthic invertebrates. Freshwater Biological Association, Scientific Publication No. 25. Windemere Laboratory, The Ferry house, Ambleside, Cumbria, England LA22 0LP

Hemming, C. R. 1995. Fisheries enhancement investigations in the Prudhoe Bay and Kuparuk River oilfields, 1993. Alaska Department of Fish and Game, Habitat and Restoration Division, Tech. Rep. 95-3.

Howe, A. H., G. Fidler and M. J. Mills. 1995. Harvest, catch and participation in Alaska sport fisheries during 1994. Alaska Department of Fish and Game, Fishery Data Series No. 95-24, Anchorage.

Howe, A. H., G. Fidler, A. E. Bingham and M. J. Mills. 1996. Harvest, catch and participation in Alaska sport fisheries during 1995. Alaska Department of Fish and Game, Fishery Data Series No. 96-32, Anchorage.

Howe, A. H., R. J. Walker, C. Olnes, K. Sundet and A. E. Bingham. 2001a. Revised Edition: Harvest, catch and participation in Alaska sport fisheries during 1996. Alaska Department of Fish and Game, Fishery Data Series No. 97-29 (revised), Anchorage.

Howe, A. H., R. J. Walker, C. Olnes, K. Sundet and A. E. Bingham. 2001b. Revised Edition: Harvest, catch and participation in Alaska sport fisheries during 1997. Alaska Department of Fish and Game, Fishery Data Series No. 98-25 (revised), Anchorage.

Howe, A. H., R. J. Walker, C. Olnes, K. Sundet and A. E. Bingham. 2001c. Revised Edition: Participation, catch and harvest in Alaska sport fisheries during 1998. Alaska Department of Fish and Game, Fishery Data Series No. 99-41 (revised), Anchorage.

Howe, A. H., R. J. Walker, C. Olnes, K. Sundet and A. E. Bingham. 2001d. Revised Edition: Participation, catch and harvest in Alaska sport fisheries during 1998. Alaska Department of Fish and Game, Fishery Data Series No. 01-8 (revised), Anchorage.

Jennings, G. B., K. Sundet, A.E. Bingham and H. K Sigurdsson. *In prep*. Participation, catch and harvest in Alaska sport fisheries during 2001. Alaska Department of Fish and Game, Fishery Data Series, Anchorage.

Jennings, T. R. 1983. Survival, growth and food habits of age-0 Arctic grayling stocked in barren, sub-Arctic lakes. Master of Science Thesis, University of Alaska, Fairbanks, AK.

Kline, T. C., J. J. Goering, and R. J. Piorkowski. 1997. The effect of salmon carcasses on Alaskan freshwaters *in* A. M. Milner and M. W. Oswood *editors*. Freshwaters of Alaska, Ecological Studies V. 119, Springer-Verlag New York, Inc.

Mills, M. J. 1981. Alaska statewide sport fish harvest studies (1980). Alaska Department of Fish and Game, Federal Aid in Fish Restoration, Annual Performance Report, 1980-1981, Project F-9-13, 22(SW-I-A), Juneau.

Mills, M. J. 1982. Alaska statewide sport fish harvest studies (1981). Alaska Department of Fish and Game, Federal Aid in Fish Restoration, Annual Performance Report, 1981-1982, Project F-9-14, 23(SW-I-A), Juneau.

Mills, M. J. 1983. Alaska statewide sport fish harvest studies (1982). Alaska Department of Fish and Game, Federal Aid in Fish Restoration, Annual Performance Report, 1982-1983, Project F-9-15, 24(SW-I-A), Juneau.

Mills, M. J. 1984. Alaska statewide sport fish harvest studies (1983). Alaska Department of Fish and Game, Federal Aid in Fish Restoration, Annual Performance Report, 1983-1984, Project F-9-16, 25(SW-I-A), Juneau.

Mills, M. J. 1985. Alaska statewide sport fish harvest studies (1984). Alaska Department of Fish and Game, Federal Aid in Fish Restoration, Annual Performance Report, 1984-1985, Project F-9-17, 26(SW-I-A), Juneau.

REFERENCES CITED (Continued)

Mills, M. J. 1986. Alaska statewide sport fish harvest studies (1985). Alaska Department of Fish and Game, Federal Aid in Fish Restoration, Annual Performance Report, 1985-1986, Project F-10-1, 27(RT-2), Juneau.

Mills, M. J. 1987. Alaska statewide sport fish harvest studies (1986). Alaska Department of Fish and Game, Fishery Data Series No. 2, Juneau.

Mills, M. J. 1988. Alaska statewide sport fish harvest studies (1987). Alaska Department of Fish and Game, Fishery Data Series No. 52, Juneau.

Mills, M. J. 1989. Alaska statewide sport fish harvest studies (1988). Alaska Department of Fish and Game, Fishery Data Series No. 122, Juneau.

Mills, M. J. 1990. Harvest and participation in Alaska sport fisheries during 1989. Alaska Department of Fish and Game, Fishery Data Series No. 90-44, Anchorage.

Mills, M. J. 1991. Harvest, catch, and participation in Alaska sport fisheries during 1990. Alaska Department of Fish and Game, Fishery Data Series No. 91-58, Anchorage.

Mills, M. J. 1992. Harvest, catch, and participation in Alaska sport fisheries during 1991. Alaska Department of Fish and Game, Fishery Data Series No. 92-40, Anchorage.

Mills, M. J. 1993. Harvest, catch, and participation in Alaska sport fisheries during 1992. Alaska Department of Fish and Game, Fishery Data Series No. 93-42, Anchorage.

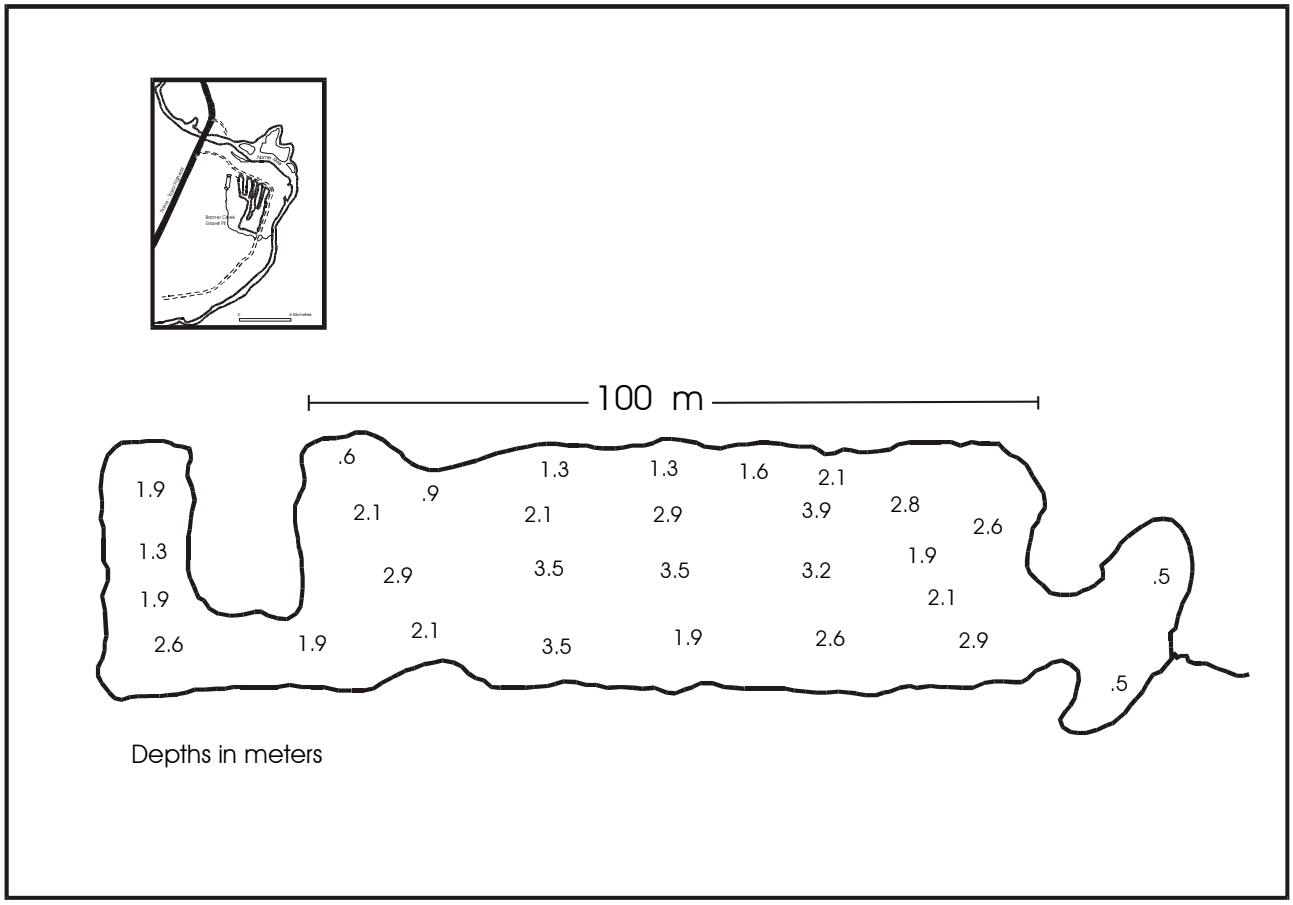
Mills, M. J. 1994. Harvest, catch, and participation in Alaska sport fisheries during 1993. Alaska Department of Fish and Game, Fishery Data Series No. 94-28, Anchorage.

Scholz, F. W., and M. A. Stephens. 1987. K-sample Anderson-Darling tests. Journal of the American Statistical Association 82:918-924.

Walker, R. J., C. Olnes, K Sundet, A. L. Howe and A. E, Bingham. 2003. Participation, catch and harvest in Alaska sport fisheries during 2000. Alaska Department of Fish and Game, Fishery Data Series No. 03-05, Anchorage.

APPENDIX A

Appendix A1.-The Banner Creek Pond with depth measurements.



APPENDIX B

Appendix B1.-Conversions from length to weight used to estimate feeding rates for Arctic grayling fry in pens.

Average Length (mm)	Estimated Weight (g)	Average Length (mm)	Estimated Weight (g)	Average Length (mm)	Estimated Weight (g)	Average Length (mm)	Estimated Weight (g)
15	0.025	42	0.626	69	2.977	96	8.402
16	0.030	43	0.674	70	3.115	97	8.680
17	0.037	44	0.724	71	3.257	98	8.964
18	0.044	45	0.777	72	3.403	99	9.255
19	0.052	46	0.833	73	3.554	100	9.552
20	0.061	47	0.891	74	3.709	101	9.855
21	0.071	48	0.952	75	3.869	102	10.165
22	0.082	49	1.016	76	4.033	103	10.481
23	0.094	50	1.082	77	4.202	104	10.804
24	0.108	51	1.152	78	4.376	105	11.134
25	0.123	52	1.224	79	4.555	106	11.470
26	0.139	53	1.300	80	4.738	107	11.814
27	0.156	54	1.378	81	4.927	108	12.164
28	0.175	55	1.460	82	5.121	109	12.522
29	0.196	56	1.545	83	5.319	110	12.886
30	0.217	57	1.634	84	5.523	111	13.258
31	0.241	58	1.725	85	5.732	112	13.636
32	0.266	59	1.820	86	5.947	113	14.023
33	0.293	60	1.919	87	6.167	114	14.416
34	0.322	61	2.021	88	6.392	115	14.817
35	0.353	62	2.127	89	6.623	116	15.226
36	0.386	63	2.237	90	6.860	117	15.642
37	0.420	64	2.351	91	7.102	118	16.066
38	0.457	65	2.468	92	7.350	119	16.497
39	0.496	66	2.589	93	7.604	120	16.937
40	0.537	67	2.714	94	7.864		
41	0.580	68	2.844	95	8.130		