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EVALUATION OF ARCTIC GRAYLING ENHANCEMENT IN ALASKA DURING 1987[1]

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ABSTRACT

Fourteen ponds and lakes in the Fairbanks, Delta Junction, Glennallen, and Palmer areas were stocked with Arctic grayling *Thymallus Arcticus* sac fry, 4 gram fingerling, and 6 gram fingerling in 1986. In 1987, the estimated survivals of grayling in these stocking groups were 0.08 (standard error = 0.02), 0.63 (standard error = 0.02), and 0.75 (standard error = 0.02), respectively. The estimated costs per survivor were $1.58 (standard error = 0.15), $0.24 (standard error = 0.01), and $0.21 (standard error = 0.01), respectively. The mean cost per survivor was significantly different between sac fry and 6 gram fingerling ($q = 52$, $q_{(0.05,25,3)} = 3.5$) and between sac fry and 4 gram fingerling ($q = 50$, $q_{(0.05,25,3)} = 3.5$). There was no significant difference between 4 gram and 6 gram fingerling ($q = 1.2$, $q_{(0.05,25,3)} = 3.5$) The cost per survivor was lower for stocked fingerling than for stocked sac fry in 11 of the 13 lakes. However, the single lowest cost per survivor was for sac fry stocked in a barren lake.

Twelve other ponds in the Fairbanks area were stocked with either sac fry or 4 gram fingerling in 1986. Grayling were captured in only five of these ponds. The cost per survivor ranged from $0.13 to $2.60 for four of these ponds.

Pond reared and hatchery reared grayling were stocked in the Delta Clearwater River in August and September, 1986. The estimated survival from 1986 to 1987 for pond reared grayling stocked in August and September was 0.06 (standard error = 3.47×10^{-3}) and 0.06 (standard error = 2.34×10^{-3}), respectively. The estimated survival for hatchery reared grayling stocked in August and September was 0.02 (standard error = 1.9×10^{-3}) and 0.02 (standard error = 1.86×10^{-3}), respectively.

When the number of grayling stocked was compared to the number of grayling captured there was no significant difference between stocking time among rearing methods (pond: $\chi^2 = 0.28$, $p = 0.60$; hatchery: $\chi^2 = 0.002$, $p = 0.96$;). However, there were significant differences between rearing methods ($\chi^2 = 187$, $p = 0.0001$). Overall, pond reared grayling stocked in either August or September had the best survival rates.

KEY WORDS: Arctic grayling, *Thymallus arcticus*, enhancement techniques, stocking time, stocking size, rearing methods, Delta Clearwater River, lakes and ponds, growth, survival.

INTRODUCTION

The Arctic grayling *Thymallus Arcticus* enhancement evaluation project consisted of two separate studies during 1987. The first study (Lake Study) was initiated in 1986 to evaluate the survival of Arctic grayling (hereafter referred to as grayling) stocked as sac fry, 4 g fingerling, and 6 g fingerling in lakes and roadside ponds in the Fairbanks-Delta Junction, Glennallen, and Palmer areas. The second study (River Study) was started in 1975 to evaluate the survival, growth, and contribution to the sport fishery of pond reared grayling fingerling that were stocked in the Delta Clearwater River, near Delta Junction. In 1983, the river study was expanded to include the evaluation of hatchery reared grayling fingerling stocked in the Delta Clearwater River. Preliminary results obtained from these studies are presented under separate chapters in this report.

CHAPTER 1 - LAKE STUDY

Introduction

To improve sport fishing opportunities, the Alaska Department of Fish and Game (ADF&G) has stocked Arctic grayling sac fry into lakes since 1961 (Van Wyhe 1963). Using improved fish culture techniques, the ADF&G can now grow grayling to fingerling size (D. Parks, ADF&G, personal communication). Al Havens (ADF&G, personal communication) found that in two barren lakes the relative survival rate after 11 months was higher for stocked fingerling than for stocked sac fry (2.4:1). In lakes that have stickleback, the relative survival rate after 11 months was much higher for stocked fingerling than for stocked sac fry (101:1).

Because survival rates are higher for grayling fingerling, they may be more desirable to stock than sac fry. However, fingerling grayling are more expensive to produce than sac fry because of the added rearing costs in the hatchery. This study was designed to compare the cost per survivor for grayling stocked as sac fry and fingerling.

In 1987, the cost per survivor for grayling stocked as sac fry or fingerling was estimated with two types of experiments: multiple size group stocking and single size group stocking. In the multiple size group stocking experiment, sac fry and two sizes of fingerling were stocked together in the same lakes in 1986. In the single size group stocking experiment, sac fry and fingerling were stocked in different lakes. The single size group experiment is being conducted over a 3 year period. In 1987, lakes that were stocked with sac fry in 1986 were stocked with fingerling and lakes that were stocked with fingerling in 1986 were stocked with sac fry. The multiple size group experiment has the advantage of identical environmental conditions for each treatment and the disadvantages of possible intraspecific competition, possible differential mortality from finclips, and treatments that are unlike standard stocking procedures. The single size group stocking experiment uses standard stocking procedures, requires no finclipping, and results in no intraspecific competition, however, treatments will be exposed to different climatic conditions between years.

The goal of the lake and pond study was to determine the optimum size (weight) at which to stock hatchery reared young-of-the-year Arctic grayling based on a cost per survivor analysis.

Specific objectives of the lake and pond study in 1987 were:

1. to estimate population abundance during the summer of 1987 of Arctic grayling cohorts (unfed sac fry, 4 g fingerling, and 8 g fingerling) stocked in 1986 in each of 14 lakes and ponds listed in Tables 1 and 2;

2. to estimate winter survival rates of each stocking cohort in each of the 26 lakes and ponds listed in Tables 1, 2 and 4;

3. to estimate cost per survivor for each stocking cohort in each of 26 lakes and ponds listed in Tables 1, 2 and 4; and

4. to estimate the average length for each stocking cohort of Arctic grayling in each of 26 lakes and ponds listed in Tables 1, 2 and 4.

Procedures

Multiple Size Group Experiment:

In 1986, 14 lakes were stocked with grayling in the Fairbanks-Delta Junction, Glennallen, and Palmer areas (Tables 1 and 2). These areas were selected because they have on-going Arctic grayling stocking programs. The individual lakes and ponds were chosen based on small acreage, accessibility, and ease of sampling. They represent a mix of physical and biological environments. Four lakes have no competing species, four lakes have previously stocked Arctic grayling, and six lakes have other species such as rainbow trout *Salmo gairdneri*, threespine stickleback, or lake trout *Salvelinus namaycush*.

Three size groups of grayling were stocked into each lake at different times of the year: (1) 1-4 day old sac fry were stocked in mid-June; (2) 4 g fingerling were stocked in August; and (3) 6 g fingerling were stocked in September. All three size groups of grayling came from the Moose Lake brood stock. The 4 g and 6 g fingerling were marked at Clear Hatchery at the same time with left and right pelvic finclips, respectively. The stocking times and the fingerling sizes were based on the space and time constraints of Clear Hatchery. The sac fry were stocked at 2,000 per acre. The 4 g and 6 g fingerling were each stocked at 100 per acre. The stocking density for the sac fry was based on an average of prior survival rates estimated by Holmes (1985) and Ridder (1985) for grayling stocked in summer rearing ponds. The stocking density for the fingerling was based on survival rates estimated for coho salmon and rainbow trout fingerling (Mike Doxey, ADF&G, personal communication).

Fyke nets were used to capture grayling during May and June 1987. All captured grayling were examined for finclips, measured to the nearest millimeter, marked by removing the adipose fin, and released. This process was

Table 1. Pond and lake locations, estimated absolute abundance, survival rates, and cost per survivor for ponds stocked with sac fry, 4 g, and 6 g fingerling Arctic grayling.

Area and Location	Stocking Size	Number Stocked	Estimated Abundance	Standard Error	Survival Rate	Standard Error	Stocking Cost	Cost Per Survivor	Standard Error	Other [1] Species
Fairbanks										
31.6 mi Steese	Sac fry	4,000	133	3.48	0.033	0.0009	$80.00	$0.60	0.011	BB,GR
	4 gram	200	1	0.09	0.005	0.0005	$23.20	$22.16	6.42	
	6 gram	200	0		0		$27.68			
34.6 mi Steese	Sac fry	8,000	59	20.91	0.008	0.0026	$160.00	$2.71	0.64	GR
	4 gram	400	359	13.37	0.90	0.033	$46.40	$0.13	0.008	
	6 gram	400	386	14.41	0.97	0.036	$55.36	$0.14	0.008	
32.9 mi CHSR	Sac fry	10,000	4	0.14	0.0004	0	$200.00	$45.26	29.83	GR
	4 gram	500	258	6.60	0.52	0.013	$58.00	$0.23	0.013	
	6 gram	500	379	9.67	0.76	0.019	$69.20	$0.18	0.007	
Delta Junction										
Luke Lake	Sac fry	10,000	4,980	1,462	0.50	0.15	$200.00	$0.04	0.002	Barren
	4 gram	500	110	49	0.22	0.098	$58.00	$0.53	0.15	
	6 gram	500	162	75	0.32	0.15	$69.20	$0.43	0.095	
Sheefish Lake	Sac fry	10,000	239	28.93	0.024	0.0029	$200.00	$0.84	0.14	GR
	4 gram	500	486	59.07	0.97	0.12	$58.00	$0.12	0.015	
	6 gram	500	383	46.43	0.77	0.093	$69.20	$0.18	0.026	
Glennallen										
Junction Lake	Sac fry	36,000	658	13.00	0.02	0.0004	$720.00	$1.09	0.050	GR
	4 gram	1,800	647	12.79	0.36	0.0071	$208.80	$0.32	0.015	
	6 gram	1,800	772	15.24	0.43	0.0085	$249.12	$0.32	0.012	
Buffalo Lake	Sac fry	10,000	74	5.37	0.007	0.0005	$200.00	$2.70	0.37	RB
	6 gram	500	350	25.38	0.70	0.051	$69.20	$0.20	0.014	
Kettle Lake	Sac fry	12,000	0[2]							BB,LS
	4 gram	600	0[2]							
	6 gram	600	0[2]							
Palmer										
Farmer Lake	Sac fry	42,000	0	0	0	0	$840.00			GR
	4 gram	1,610	819	11.23	0.51	0.0070	$186.76	$0.23	0.007	
	6 gram	2,080	1,363	18.67	0.66	0.0090	$287.87	$0.21	0.004	
Sliver Lake	Sac fry	14,400	0	0	0	0	$288.00			GR
	4 gram	720	243	7.06	0.34	0.0098	$83.52	$0.34	0.021	
	6 gram	720	533	15.52	0.74	0.022	$99.65	$0.19	0.007	
Meirs Lake	Sac fry	33,600	600	23.62	0.018	0.0007	$672.00	$1.12	0.074	TSS
	4 gram	1,695	1,496	58.92	0.88	0.035	$196.62	$0.13	0.005	
	6 gram	1,680	1,916	75.46	1.14	0.045	$232.51	$0.12	0.005	
Canoe Lake	Sac fry	42,400	238	25.41	0.0056	0.0006	$848.00	$3.57	0.89	TSS
	4 gram	1,207	1,140	122.94	0.94	0.10	$140.01	$0.12	0.022	
	6 gram	2,120	2,128	229.71	1.00	0.11	$293.41	$0.14	0.022	

[1] Other species: BB = burbot; RB = Rainbow trout; LS = Longnose sucker; TSS = Threespine stickleback; GR = Previously stocked grayling.

[2] No fish were captured or seen in this lake.

Table 2. Pond and lake locations, relative abundance, survival rates, and cost per survivor for ponds stocked with sac fry, 4 g, and 6 g fingerling Arctic grayling.

Area and Location	Stocking Size	Number Stocked	Sample Size	Relative Abundance	Standard Error	Relative Cost	Other Species[1]
Fairbanks							
47.9 mi CHSR	Sac fry	8,000	38	0.49	0.057	1.9	BB
	4 gram	400	21	0.27	0.051	1	
	6 gram	400	19	0.24	0.049	1.3	
Glennallen							
Squirrel Ck Pit	Sac fry	10,000	8	0.078	0.027	28.9	RB
	4 gram	500	15	0.15	0.035	4.5	
	6 gram	500	80	0.78	0.041	1	

[1] Other Species: BB = burbot; RB = Rainbow trout.

repeated until the desired precision and accuracy of the abundance estimate was reached. If objective criteria were not obtained, sampling was stopped after the seventh event. For the ponds in the Fairbanks-Delta Junction area, a final sampling event was conducted during September and October.

For each lake sampled only during May and June, the absolute abundance of all age 1 Arctic grayling was estimated using Chapman's modification of Schnabel's formula (Seber 1982):

$$(1) \quad \hat{N}_k = \frac{\lambda}{1 + \sum m_{ik}} \qquad (2) \quad V(\hat{N}_k) = N^2(N/\lambda + 2N^2/\lambda^2 + 6N^3/\lambda^3)$$

where:

$\hat{N}_k$ = abundance estimate in lake k;

n_{ik} = sample size of the ith sample in lake k;

m_{ik} = number of marked individuals in n_{ik}; and,

M_{ik} = number of marked individuals in the population just before the i^{th} sample is taken.

$\lambda = \sum n_{ik}M_{ik}$

The absolute abundance and associated variance were calculated for each size group for each lake using the formulas:

$$(3) \quad \hat{q}_{jk} = \frac{\sum_i (n_{ijk} - m_{ijk})}{\sum_i \sum_j (n_{ijk} - m_{ijk})} \qquad (4) \quad V\overset{C}{[q_{jk}]} = \frac{\hat{q}_{jk}\,(1 - \hat{q}_{jk})}{\sum_i \sum_j (n_{ijk} - m_{ijk}) - 1}$$

$$(5) \quad \hat{N}_{jk} = \hat{N}_k\,\hat{q}_{jk} \qquad (6) \quad V[\hat{N}_{jk}] = V[\hat{N}_k]\hat{q}_{jk}^2 + V[\hat{q}_{jk}]\hat{N}_k^2 - V[\hat{q}_{jk}]V[\hat{N}_k]$$

where:

$\hat{N}_{jk}$ = abundance estimate for group j in lake k;

n_{ijk} = sample size of the ith sample for group j in lake k;

m_{ijk} = number of marked individuals in n_{ijk}; and,

$\hat{q}_{jk}$ = the estimated fraction of Age 1 Arctic grayling in lake k composed of group j.

For each lake, the total abundance was estimated by pooling the data from all size groups. The total abundance was then apportioned into estimates of abundance within specific size groups. This method was used because it usually

gives smaller variances compared to individually estimating the abundance of each size group (Seber 1982).

The survival rate for each group was calculated as follows:

$$(7) \quad \hat{S}_{jk} = \frac{\hat{N}_{jk}}{N_{jko}} \quad (8) \quad V[\hat{S}_{jk}] = \frac{V[\hat{N}_{jk}]}{N_{jko}^2}$$

where:

$\hat{S}_{jk}$ = the estimated survival rate of group j in lake k; and,

N_{jko} = the number of Arctic grayling of group j stocked in lake k.

The estimate of cost per survivor was calculated as:

$$(9) \quad \hat{C}_{jk} = \frac{N_{jko}\, C_{hj}}{\hat{N}_{jk}}$$

where:

$\hat{C}_{jk}$ = estimated cost per survivor of group j in lake k; and,

C_{hj} = hatchery cost of producing a single fish for group j.

The variance of $\hat{C}_{jk}$ was estimated through resampling techniques (Efron 1982) on the original data.

When the number of recaptured fish was less than 10 the relative survival rate was calculated as follows:

$$(10) \quad \hat{p}_{jk} = \frac{n_{jk}}{n} \quad (11) \quad V[\hat{p}_{jk}] = \frac{\hat{p}_{jk}(1-\hat{p}_{jk})}{n-1}$$

where:

n_{jk} = the number in the sample from group j in lake k;

n = the sample size; and,

$\hat{p}_{jk}$ = the estimated fraction of the stocked population that is made up of group j in lake k.

When Equation 9 was used the relative cost per survivor was calculated as follows:

(12) $\hat{C}_{jk} = C_{hj} N_{jko} / n_{jk}$

The average lengths and their variances were calculated as follows:

(13) $\bar{x} = \frac{\sum x_i}{n}$ (14) $V[\bar{x}] = (1 - f)\frac{\sum (x_i - \bar{x})^2}{n (n - 1)}$

where:

x_i = an individual length measurement;

$\bar{x}$ = the average length of the sample;

n = the sample size [i.e $\sum_i (n_{ijk} - m_{ijk})$]; and,

f = the finite population correction factor (= n/N).

The average cost per survivor for sac fry, 4 g fingerling, and 6 g fingerling was calculated as follows:

(15) $\bar{x}_j = \frac{\sum x_{jk}}{n_{jk}}$ (16) $V[\bar{x}_j] = \frac{\sum \bar{x}_j}{n_j^2}$

where:

x_{jk} = the estimated cost per survivor of the j^{th} group in lake k where the estimated abundance of the j^{th} group is greater than 50;

n_{jk} = the sample size of j^{th} group;

$\bar{x}_j$ = the mean cost per survivor of the j^{th} group; and,

$V[\bar{x}_j]$ = the variance of the mean cost per survivor of the j^{th} group.

Single Size Group Experiment:

In 1986, 10 ponds were stocked with sac fry. Two other ponds were stocked with 4 g fingerling from the Clear Hatchery (Table 3). These 12 ponds represent the majority of small lakes traditionally stocked with Arctic grayling in the Tanana River drainage. All of these ponds are about five acres in size.

In 1987, the stocking procedures were reversed: ponds that were stocked with fry in 1986 were stocked with fingerling and the ponds stocked with fingerling in 1986 were stocked with fry in 1987. All fish came from the same Moose Lake stock as those used in the multiple size group stocking experiment. In 1987, the abundance of age 1 grayling was estimated in each of the ponds using the

Table 3. Mean lengths of age 1 Arctic grayling captured one year after stocking as sac fry, 4 g, and 6 g fingerling.

Area Location	Stocking Size	Sample Size	Mean Length(mm)	Standard Error	Range Low	Range High
Fairbanks						
31.6 mi Steese	Sac fry	99	114	0.61	94	128
	4-gram	1	109		109	109
	6-gram	0				
34.6 Steese	Sac fry	35	100	1.20	82	112
	4-gram	258	92	0.32	76	109
	6-gram	277	94	0.40	78	110
32.9 mi CHSR	Sac fry	3	110	5.36	99	116
	4-gram	178	116	0.61	91	135
	6-gram	270	113	0.54	90	140
47.9 mi CHSR	Sac fry	38	103	1.39	85	118
	4-gram	21	93	0.98	84	102
	6-gram	19	92	1.92	83	114
Delta Junction						
Luke Lake	Sac fry	447	171	0.38	114	196
	4-gram	24	124	1.14	113	138
	6-gram	38	121	1.44	104	141
Sheefish Lake	Sac fry	60	120	2.47	77	158
	4-gram	121	120	0.85	96	142
	6-gram	97	119	1.04	90	148
Glennallen						
Junction Lake	Sac fry	499	118	0.57	59	148
	4-gram	491	106	0.41	77	172
	6-gram	584	104	0.40	73	128
Buffalo Lake	Sac fry	47	141	2.34	98	162
	6-gram	221	119	0.54	102	150
Squirrel Ck Pit	Sac fry	8	138	6.30	118	165
	4-gram	15	130	2.00	115	145
	6-gram	80	130	1.37	101	159
Palmer						
Farmer Lake	Sac fry	0				
	4-gram	151	85	0.54	72	102
	6-gram	296	90	0.33	69	111
Sliver Lake	Sac fry	0				
	4-gram	110	86	0.86	65	112
	6-gram	332	98	0.55	74	128
Meirs Lake	Sac fry	148	176	1.09	151	219
	4-gram	270	134	0.59	96	156
	6-gram	356	129	0.54	98	169
Canoe Lake	Sac fry	32	194	1.85	167	212
	4-gram	127	141	0.94	116	171
	6-gram	188	137	0.82	99	169

same methods described for the multiple size group experiment. The abundance of those fish stocked in 1987 will be estimated in 1988.

Results

Multiple Size Group Experiment:

In 1987, the abundance of age 1 Arctic grayling was estimated in 13 of the 14 lakes that had been stocked in 1986 with sac fry, 4 g, and 6 g fingerling (Tables 1 and 2). No grayling were captured in Kettle Lake. Grayling stocked as fingerling (4 g and 6 g combined) were more abundant than sac fry in 11 of 13 lakes. Grayling stocked as sac fry were more abundant in only two lakes. The mean survival rates for sac fry, 4 g, and 6 g fingerling were 0.08 (SE = 0.02), 0.63 (SE = 0.02), and 0.75 (SE = 0.02), respectively. Sac fry were not captured in Farmer and Sliver lakes which have populations of threespine stickleback. However, the survival rate or relative abundance of sac fry was higher than the survival rate of fingerling in three lakes which have populations of burbot or were barren.

The mean costs per survivor for sac fry, 4 g, and 6 g fingerling were \$1.58 (SE = 0.15), \$0.24 (SE = 0.01), and \$0.21 (SE = 0.01), respectively. Analysis of variance (Zar 1984) indicated that at least one of the mean costs was significantly different ($F_{(0.05,2,25)} = 3.39$, $p < 0.0005$). The results of Tukey's test for multiple comparisons show that the mean cost per survivor was significantly different between sac fry and 6 g fingerling ($q = 52$, $q_{(0.05,25,3)} = 3.5$) and between sac fry and 4 g fingerling ($q = 50$, $q_{(0.05,25,3)} = 3.5$). There was no significant difference in mean costs between 4 g and 6 g fingerling ($q = 1.2$, $q_{(0.05,25,3)} = 3.5$) The cost per survivor was lower for stocked fingerling than for stocked sac fry in 11 of the 13 lakes (Tables 1 and 2). However, the single lowest cost per survivor was for sac fry stocked in a barren lake (Luke Lake, Table 1).

When captured in spring 1987, grayling stocked as sac fry were larger on average than either size group of grayling stocked as fingerling in all lakes except Farmer Lake, Sliver Lake, and Chena Hot Springs Road (CHSR) 32.9 mile pond (Table 3). No stocked sac fry were captured in either Farmer Lake or Sliver Lake and only four stocked sac fry were captured in the CHSR pond. The average lengths of the stocked 4 g fingerling were larger than the average lengths of stocked 6 g fingerling in all lakes except Farmer Lake and Sliver Lake.

Single Size Group Experiment:

In 1987, Arctic grayling were captured in only five of the 12 ponds that had been stocked with either sac fry or 4 g fingerling in 1986. No grayling were captured that had been stocked as 4 g fingerling. The cost per survivor of grayling stocked as sac fry ranged from \$0.13 to \$2.60 in four of these ponds (Table 4). The lowest and highest costs per survivor were in ponds that were also stocked with rainbow trout the same year. The average lengths of age 1 grayling stocked as sac fry ranged from 123 mm to 187 mm (Table 5).

Table 4. Pond and lake locations, estimated absolute abundance, survival rates, and cost per survivor for ponds stocked with either sac fry or 4 g fingerling Arctic grayling.

Area and Location	Stocking Size	Number Stocked	Estimated Abundance	Standard Error	Survival Rate	Standard Error	Stocking Cost	Cost Per Survivor	Standard Error	Other Species[1]
Steese Highway										
Terry's (29.5 mi)	Sac fry	10,000	1,333	111.22	0.13	0.0111	$200.00	$0.15	0.012	BB,CS,WF
Rocky's (30.6 mi)	Sac fry	10,000	10		TN0					Barren
Poop (35.8 mi)[2]	Sac fry	10,000	0		0					Barren
John's (36.6 mi)	Sac fry	10,000	668	160.27	0.084	0.016	$200.00	$0.30	0.060	BB
Chena Hot Springs Road										
Walden Pond[2] (17 mi)	4-gram	1,500	0		0					Barren
Bumpy's[3] (42.8 mi)	Sac fry	10,000	0		0					
Arwen's (45.5 mi)	Sac fry	10,000	1,568	111.67	0.16	0.0112	$200.00	$0.13	0.009	RB
Richardson Highway										
Bathing Beauty	Sac fry	10,000	77	1.57	0.0077	0.0002	$200.00	$2.60	0.031	RB
Hidden Lake[3]	Sac fry	10,000	0		0					CH,LS
Grayling Lake[4]	Sac fry	10,000	0		0					NP
Fort Greely										
Skaugstad[2]	4-gram	500	0		0					Barren
Johnson Road										
Pit #2[2]	Sac fry	10,000	0		0					Barren

[1] Other species: BB = burbot; RB = Rainbow trout; LS = Longnose sucker; TSS = Threespine stickleback; GR = Previously stocked grayling; NP = northern pike; CH = lake chub.

[2] No fish were captured or seen in these ponds.

[3] Less than twenty grayling captured; no recaptures.

[4] Twelve northern pike captured, one recapture.

Table 5. Mean lengths of Arctic grayling captured one year after stocking as sac fry.

Area Location	Stocking Size	Sample Size	Mean Length(mm)	Standard Error	Range Low	Range High
Steese Highway						
Terry's (29.5 mi)	Sac fry	50	123	0.92	107	137
John's (36.6 mi)	Sac fry	317	132	0.39	115	155
Chena Hot Springs Road						
45.5 mi CHSR	Sac fry	131	148	0.80	107	168
Richardson Highway						
Bathing Beauty	Sac fry	54	187	1.82	156	228

No fish were captured or seen in Poop, Walden, or Skaugstad's ponds. Only seven fish were captured in Rocky's pond. Less than 20 grayling were captured in Bumpy's pond or Hidden Lake. Both ponds had large populations of lake chubs, longnose suckers, or burbot. Hidden Lake had also been stocked with rainbow trout in 1986, but none were captured. No grayling were captured in Johnson Road Pit #2. Twelve northern pike were captured in Grayling Lake, but no grayling were captured.

Discussion

Multiple Size Group Experiment:

The mean cost per survivor of 4 g and 6 g fingerling stocked in 1986 was lower than for sac fry. Although the average cost of 4 g fingerling ($0.24) was slightly higher than 6 g fingerling ($0.21), the difference was not statistically significant. Therefore, when hatchery resources are needed for other programs, 4 g fingerling is probably the optimum size at which to stock grayling because they require hatchery resources for a shorter period.

Another possible advantage of stocking 4 g fingerling over 6 g fingerling is their larger size the following spring. Sac fry, 4 g, and 6 g fingerling were stocked in May, August, and September 1986, respectively. The following spring, grayling that had been stocked as sac fry were larger than grayling stocked as fingerling, and grayling stocked as 4 g fingerling were larger than grayling stocked as 6 g fingerling (Table 4). During this experiment, growth of grayling was more rapid in the lakes than in the hatchery. Even though grayling stocked as sac fry grew to a larger size than grayling stocked as fingerling, they are less desirable to stock because their survival is low which increases the cost per survivor.

Although the mean cost per survivor was lower for grayling stocked as fingerling, the single lowest cost per survivor was for sac fry stocked in Luke Lake, a barren lake (Table 1). The cost of stocking sac fry in Luke Lake in 1986 was $200. The estimated abundance in 1987 of grayling stocked as sac fry in 1986 was 4,980 (SE = 1,462). To achieve the same population size, the cost of stocking 4 or 6 g fingerling would be $580 and $690, respectively, assuming 100% survival.

The average lengths of grayling captured in Farmer Lake and Sliver Lake were less than the average lengths of grayling captured in the two other lakes in the Palmer area; Meirs Lake and Canoe Lake (Table 3). Farmer Lake and Sliver Lake contain threespine stickleback which may compete with the grayling for food. Jennings (1983) found that chironomid pupae comprised 54%-83% of the gut contents by volume of young-of-the-year grayling in a shallow 2 hectare pond. Havens (1983) found that the average lengths and weights of rainbow trout stocked in lakes that have threespine stickleback were usually less than the average lengths and weights of rainbow trout stocked in lakes that do not have threespine stickleback. Havens (1982) and Wenderoff (1982) found that rainbow trout fed mainly on zooplankton in lakes that do not have threespine stickleback but relied more on insects and benthic organisms in lakes that have threespine stickleback. Even though grayling were stocked in six lakes

with either rainbow trout or sticklebacks (Tables 1, 2, and 4), this study was not designed to investigate possible interspecific competition or predation.

Single Size Group Experiment:

In spring 1987, numbers of grayling stocked as sac fry in 10 study ponds ranged from zero in five ponds to over 1,300 fish in two ponds (each pond had been stocked with 10,000 grayling in 1986; Table 4). Past stocking of grayling sac fry in ponds resulted in highly variable survival rates. Grayling sac fry stocked in rearing-ponds in early summer and removed 3 to 4 months later had survival rates from 0.05 to 0.34 (Peckham and Ridder 1979; Ridder 1980; Holmes 1985). Most of these ponds are shallow and the grayling usually do not survive to next spring because dissolved oxygen levels fall too low or the ponds freeze to the bottom during the winter. Jennings (1983) suggests that the availability of suitable food items and physical factors such as wind induced wave action also affect survival of sac fry. All of these factors vary among lakes and from year to year and may be the cause of highly variable survival rates.

Northern pike are present in Grayling Lake, where apparent survival of sac fry was zero. Northern pike are efficient predators and may have eliminated the grayling that were stocked in the lake. Also, any grayling captured in a fyke trap may have been eaten by northern pike captured in the same trap. Estimated survival of grayling stocked as sac fry was also zero in Bumpy's and Poop ponds, Hidden Lake, and Johnson Road Pit #2. Since all these ponds have no predator or competitor species, low winter dissolved oxygen levels is the most likely cause of the high mortality rate. Johnson Road Pit #2 may not be suitable for fish because of spilled motor fuel observed at one end of the pit.

Walden Pond and Skaugstad's pond were stocked with 4 g fingerling in 1986. No fish were captured or observed in either pond in 1987. Walden Pond had also been stocked in previous years with grayling sac fry and sheefish. The pond contains large amounts of organic material and may become anoxic during the winter. Skaugstad's pond was not stocked in previous years because access is difficult. However, the pond is only about 1 meter deep and may freeze to the bottom during the winter.

CHAPTER 2 - RIVER STUDY

Introduction

The Delta Clearwater River is a clear, 30 km long, spring-fed stream that empties into the Tanana River about 23 km north of Delta Junction. The mean annual sport fishery harvest from 1977 to 1984 was 6,103 Arctic grayling. The mean annual effort for the same time period was 5,830 man-days (Ridder 1983; Mills 1984, 1985).

Arctic grayling use the Delta Clearwater River for feeding during the summer but spawn and overwinter in other nearby streams (Pearse 1974; Tack 1980; Ridder 1983). Ridder (1985) found that Arctic grayling in the Delta

Clearwater River are from stocks that spawn in the Goodpaster and Volkmar rivers and Caribou and Rapids creeks.

In 1973, enhancement of the Delta Clearwater by stocking grayling sac fry was begun because of apparent low abundance and changes in age composition of the natural population (Pearse 1974). Pearse (1975) was unable to locate these stocked fish in later sampling and the program was discontinued. However, considerable success has been achieved by rearing fry in ponds for about 3 months prior to stocking them as fingerling in the river (Peckham and Ridder 1979).

The objectives of the Delta Clearwater River Study in 1987 were:

1. to estimate the fractions of the Arctic grayling population in the Delta Clearwater River composed of hatchery reared grayling stocked as 4 g and 8 g fingerling and pond reared grayling stocked as 8 g and 12 g fingerling; and,

2. to estimate the average lengths and growth increments since stocking for the cohorts specified in Objective 1.

Procedures

During summer 1986, hatchery and pond reared young-of-the-year Arctic grayling fingerling were stocked in the Delta Clearwater River. The brood source of both hatchery and pond reared fish was the Goodpaster River. Hatchery reared 4 g and 8 g fingerling were stocked in the Delta Clearwater River in August and September, respectively (Table 6). The stocking time and the size of the hatchery reared fingerling was based on the space and time constraints of Clear Hatchery. The 4 g and 8 g hatchery reared fingerling were marked at Clear Hatchery at the same time with left ventral finclips or right pectoral finclips, respectively. 8 g and 12 g pond reared fingerling were stocked into the Delta Clearwater River in September and October, respectively (Table 6). The pond reared fingerling were marked with the same finclips as the hatchery fish and their adipose fins were also clipped.

Arctic grayling were captured in April and May of 1987 at Mile One Slough as they migrated into the Delta Clearwater River. One fyke net was set at One Mile Slough and was checked once every 24 hours. All captured Arctic grayling were measured to the nearest 1 mm, examined for finclips, marked by clipping the upper lobe of the caudal fin, and released in the Delta Clearwater River 2 miles upstream of the fyke trap.

The relative abundance and associated variance of each stocking group (stocking size and rearing method) was estimated by the following formulas (Cochran 1977):

$$(1)\quad \hat{p}_j = \frac{n_j}{n} \qquad (2)\quad V[\hat{p}_j] = \frac{\hat{p}_j(1-\hat{p}_j)}{n-1}$$

Table 6. The relative abundance, survival and average lengths of age 1 Arctic grayling captured at One Mile Slough, Delta Clearwater River, 1987.

Rearing Method	Stocking Date	Number Stocked	Number Captured	Average Length(mm) (SE)	Relative Abundance (SE)	Survival(SE)
Wild			214	85 (1)	0.17 (1.06×10^{-2})	
Pond	Aug	4,273	233	104 (1)	0.18 (1.09×10^{-2})	0.055 (3.47×10^{-3})
	Sep	9,868	563	141 (1)	0.45 (1.40×10^{-2})	0.057 (2.34×10^{-3})
Hatchery	Aug	5,748	122	90 (1)	0.10 (8.33×10^{-3})	0.021 (1.90×10^{-3})
	Sep	6,016	128	114 (1)	0.10 (8.51×10^{-3})	0.021 (1.86×10^{-3})

where:

n_j = the number in the sample from group j;

n = the sample size; and,

$\hat{p}_j$ = the estimated fraction of the stocked population that is made up of group j.

Results and Discussion

Of the 1,260 age 1 Arctic grayling captured at Mile One Slough, 83% had been stocked (only 17% were wild fish) (Table 7). The estimated relative abundance was highest for pond reared grayling stocked in September (0.45, SE = 1.96×10^{-2}; Table 7). The relative abundance of wild age 1 grayling was 0.17 (SE = 1.12×10^{-2}). Hatchery reared grayling stocked in August and September had the smallest proportions (0.10, SE = 8.33×10^{-3}; and 0.10, SE = 8.51×10^{-3}, respectively).

The estimated survival (number of grayling captured in 1987 divided by the number stocked in 1986) for pond reared grayling stocked in August and September was 0.055 (SE = 3.47×10^{-3}) and 0.057 (SE = 2.34×10^{-3}), respectively. For hatchery reared grayling stocked in August and September the estimated survival was 0.021 (SE = 1.90×10^{-3}) and 0.021 (SE = 1.86×10^{-3}).

When the number of grayling stocked was compared to the number of grayling captured there was no significant difference between stocking time among rearing methods (pond: $\chi^2 = 0.28$, $p = 0.60$; hatchery: $\chi^2 = 0.002$, $p = 0.96$; Table 7). However, there were significant differences between rearing methods ($\chi^2 = 187$, $p = 0.0001$; Table 7). Overall, pond reared grayling stocked in either August or September had the best survival rates.

It is not clear, however, if the differences between survival rates are due to rearing methods, the size of the grayling when stocked, or combinations of the two. When stocked, pond reared grayling were larger than hatchery reared grayling. Pond reared grayling stocked in August were 101 mm (SE = 1) and those stocked in September were 113 mm (SE = 1). Hatchery reared grayling stocked in August were 66 mm (SE = 1) and those stocked in September were 88 mm (SE = 1). If size is a critical factor for survival then hatchery reared grayling will always be at a disadvantage.

Overall, the results from this study indicate that survival to age 1 is best when pond reared grayling are stocked in the Delta Clearwater River in either August or September. However, there are additional manpower costs associated with trapping and transporting pond reared fish. Even though survival of pond reared fish may be up to three times that of hatchery fish, the more cost effective method may be hatchery rearing.

Table 7. Chi-square comparisons of hatchery and pond reared Arctic grayling captured at One Mile Slough, Delta Clearwater River, 1987.

Rearing Method	Date Stocked	Number Stocked	Number Captured		χ^2	p-value
			Observed	Expected		
Pond	Aug	4,273	233	240		
	Sep	9,868	563	556	0.28	0.60
Hatchery	Aug	5,748	122	122		
	Sep	6,016	128	128	0.002	0.96
Pond		14,141	796	580		
Hatchery		11,764	250	466	187	0.0001

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