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Arctic Grayling, *Thymallus arcticus*, Culture

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F-27-R

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RESEARCH PROJECT SEGMENT

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ABSTRACT

The Alaska Department of Fish and Game (ADF&G), Fisheries Rehabilitation, Enhancement and Development (FRED) and Sport Fish Divisions have coordinated efforts to enhance the important Arctic grayling, *Thymallus arcticus*, sport fishery within Alaska by artificial propagation. All fish-culture operations were conducted at Clear Hatchery.

Two separate stocks of Arctic grayling were utilized as egg sources for the production program. Moose Lake was the primary source, supplying 2,575,800 (92%) eggs; the Goodpaster River supplied 220,200 (8%) eggs. The hatchery brood stock spawned again at 3 years of age, and over 435,500 eggs were taken; unfortunately, none of the eggs survived.

Over 2.6 million Arctic grayling eggs were incubated, and 1,137,700 unfed fry were released into 22 lakes and streams statewide. Approximately 532,900 fry were used in a rearing program, and 540,600 eggs were sent to other research facilities.

Mean survival of fry during a 13-day warm-water-rearing experiment using initial water temperatures of 18°C for the control and 20°C for the test lot were 68.2% and 58.2%, respectively.

Overall survival from the fry-to-fingerling stage for healthy fish is projected at approximately 57.0%. A projected 240,000 Arctic grayling fingerlings between 4.0 and 8.0 g are to be stocked into approximately 20 lakes and rivers statewide.

KEY WORDS: Arctic grayling, *Thymallus arcticus*, rearing, Moose Lake, Goodpaster River, Jack Lake.

INTRODUCTION

Clear Hatchery is a public facility operated by ADF&G, FRED Division; it is located on Clear Air Force Base, approximately 138.4 km south of Fairbanks, Alaska on the Parks Highway (Figure 1).

The ADF&G hatchery program for Arctic grayling, *Thymallus arcticus*, has existed since 1961. Until 1983 the program consisted of taking eggs from the wild spawning stocks, incubating them to the fry stage, and releasing the unfed fry into lake systems. This program had limited success for two reasons: (1) wild Arctic grayling spawning operations are difficult to conduct and result in unpredictable problems and production goals that were rarely achieved, and (2) the survivals from the unfed-fry stage to the adult stage were very low.

Fish-cultural procedures were developed to augment survival and reduce competition and cannibalism. Successful culture of Arctic grayling fry depends on (1) the manipulation of the environment to provide adequate water flow to supply oxygen and remove metabolites, (2) suitable water temperatures for growth, and (3) a reliable commercially produced diet. Prior to 1983, all attempts at intensive Arctic grayling culture had been unsuccessful; however, subsequent research has helped to make intensive

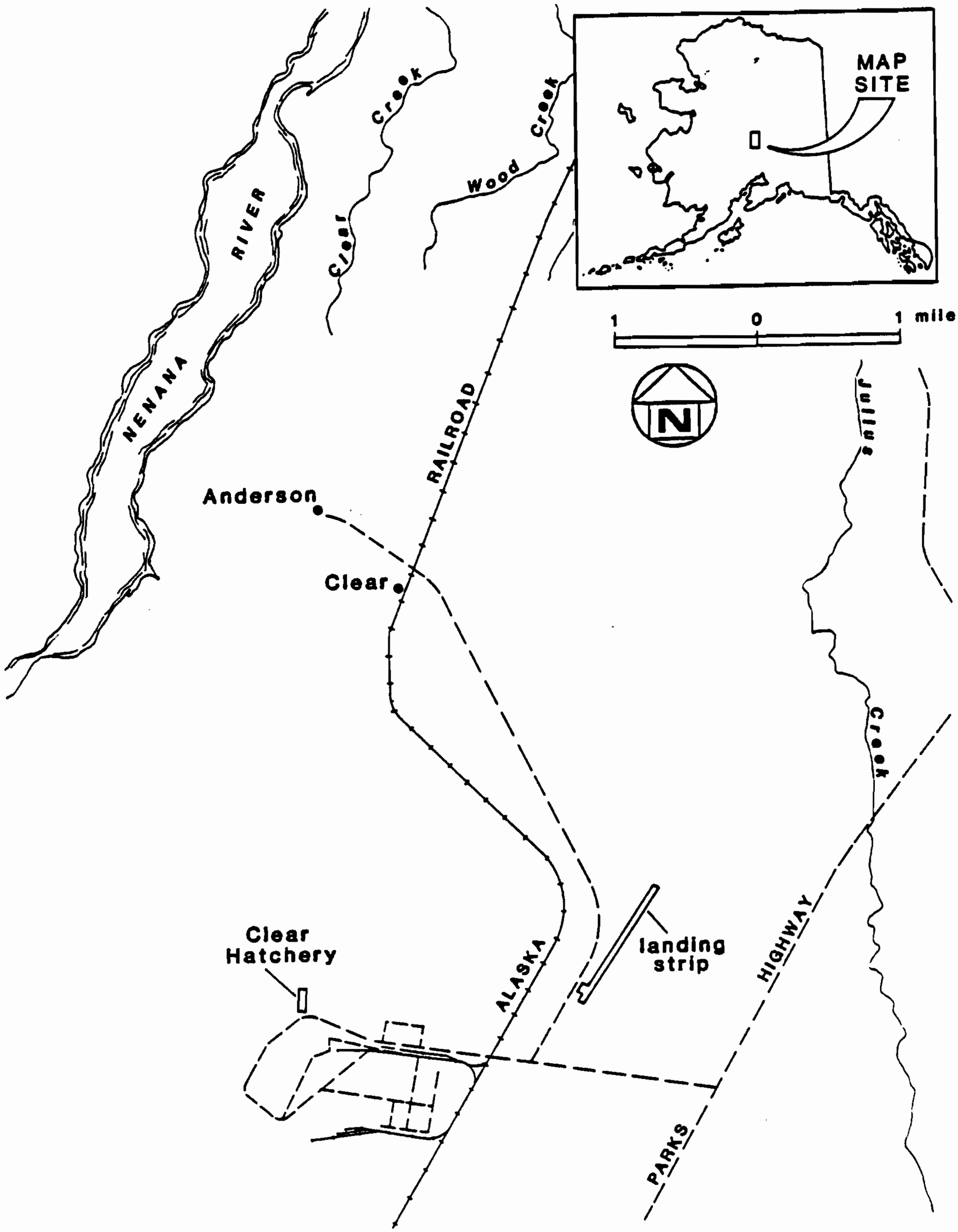

Figure 1. Location of Clear Hatchery.

culture of Arctic grayling feasible, and a fry-to-fingerling survival rate of 75% is now considered achievable.

Because one important constraint limiting the Arctic grayling enhancement program in Alaska is the problem of obtaining sufficient numbers of eggs and because the primary sources may fail, new secondary sources of wild brood stocks are being evaluated. However, the best approach in creating a predictably reliable source of eggs is to develop a hatchery brood stock. Considering the logistical constraints and expense of a wild egg take, it is well worth the effort. Previously, only Lord (1932) has reported success in establishing a small hatchery brood stock.

GOALS

The goals of the Arctic grayling program at Clear Hatchery includes two components: (1) production of fish for enhancement projects, and (2) refinement of experimental cultural techniques. We need to develop procedures and procure equipment to produce 210,000 4-g fingerlings at Clear Hatchery with a 75% survival rate from egg to fingerling; identify and develop alternate wild egg-take sources; and determine the feasibility of developing an Arctic grayling hatchery brood stock and, if feasible, implement that program.

FIVE-YEAR OBJECTIVES

1) Conduct Arctic grayling egg takes (2.0 million eggs) at Moose Lake (the primary wild brood stock) and at the Goodpaster River (for Yukon River drainage enhancement sites).

2) Continue to assess adult Arctic grayling availability at Jack, Tahneta, and Butte Lakes as alternative brood stocks.

3) Release 210,000 four-gram fingerlings in waters selected by Sport Fish Division.

4) Implement the following experimental Arctic grayling cultural techniques:

   a) Evaluate the success of egg incubation and survival to the fry stage in Heath® incubators modified with fine screens.

   b) Conduct loading experiments to determine optimal survival during incubation.

   c) Conduct rearing experiments to determine optimal conditions for growth and survival of fry fed commercially produced diets.

   d) Rear groups of fry at different loading densities in startup troughs.

   e) Rear experimental lots of fry at different light intensities.

   f) Rear experimental lots of fry at water temperatures between 14° and 20°C.

5) Rear 450 Arctic grayling to maturity and monitor growth and maturation.

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6) Successfully incubate eggs taken from brood stock grown to maturity at the hatchery.

MATERIALS AND METHODS

Brood-Stock Evaluation

Three stocks of Arctic grayling were evaluated to determine their run timing; number of available adults; and quality, quantity, and viability of eggs: (1) Moose Lake in the Copper River drainage, (2) the Goodpaster River in the Tanana River drainage (Figure 2), and (3) the Clear Hatchery experimental brood stocks originating from Jack and Moose Lakes.

Moose Lake adult Arctic grayling were captured in a wooden trap as they migrated upstream into Our Creek. Adults were dip netted from the trap, sorted according to their sex, counted, and placed in net pens to ripen.

Adult Arctic grayling from the Goodpaster River were captured by electro-fishing from a river boat. Adults were separated according to their sex, counted, and placed in net pens to ripen.

Starting 1 May 1987, the water temperature for the grayling brood-stock (resulting from eggs taken in 1984) was gradually raised from 3.7^{o} to 9.2^{o}C over a 23-day period. On 25 May 1987, the adults were anesthetized with carbon dioxide and checked to determine the presence of eggs and the degree of ripeness. The total lengths of the fish were measured (mm), and they were weighed (g) and separated into tanks according to their sex.

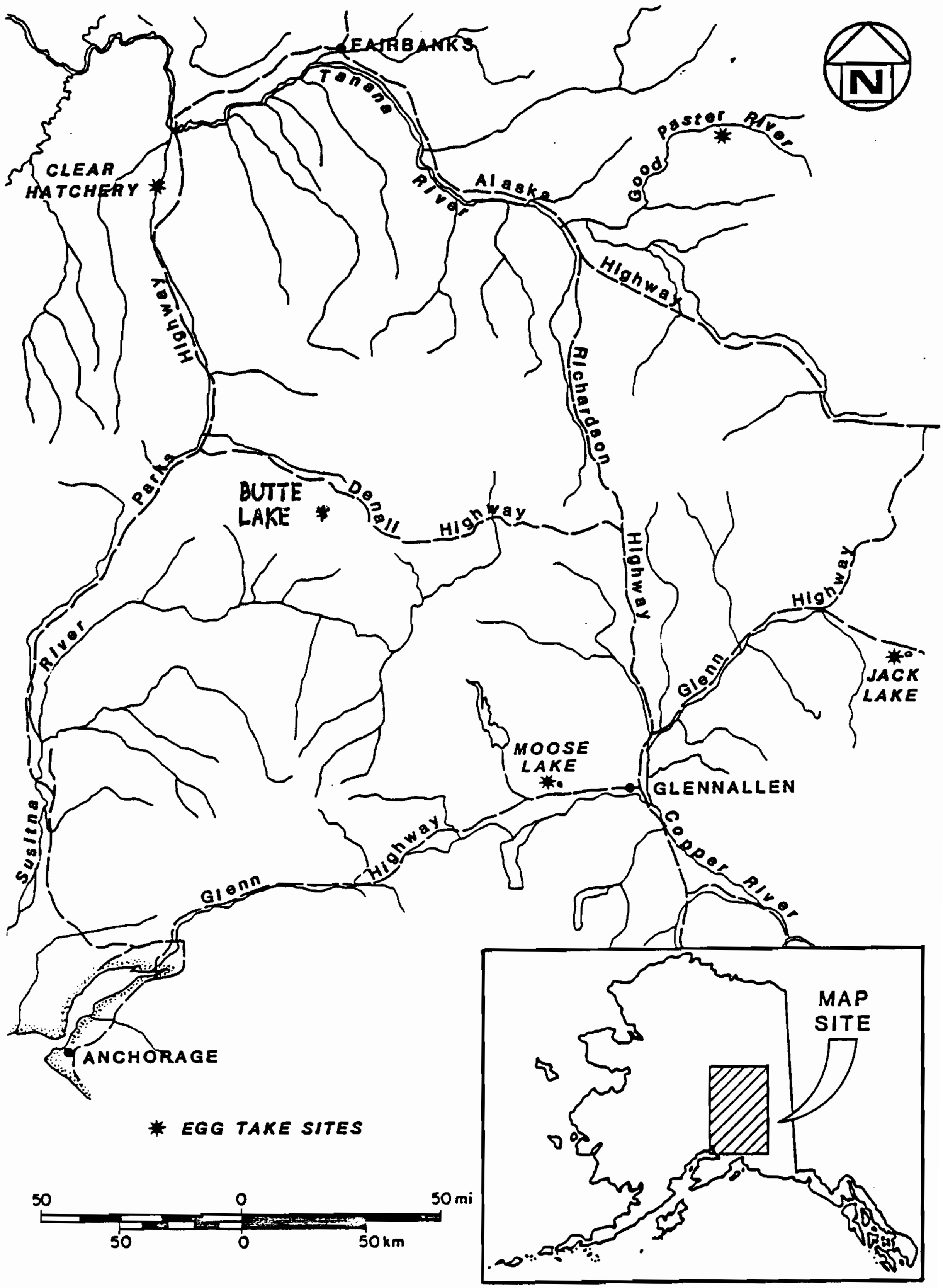

Figure 2. Location of Arctic grayling egg-take sites for Clear Hatchery.

Egg Take

Prior to spawning, adult males and females from Moose Lake and the hatchery brood stock were anesthetized with carbon dioxide; adults from the Goodpaster River were anesthetized using MS-222. All adults were spawned alive by hand-stripping. Eggs were fertilized and water hardened at the egg-take sites, cooled with lake ice, and transported to the hatchery. The eggs from Moose Lake were transported from the Gakona Airport to the Clear Airport by aircraft; the eggs from the Goodpaster River were hauled by truck directly to the hatchery.

Incubation

Eggs were disinfected for 10 min in a Betadine® (100 mg/liter) bath (Wood 1974) before they were brought into the hatchery. Each stock was totally isolated from the other stocks to minimize the likelihood of disease transmissions. Eggs were incubated in stacked Heath Techna trays with fine-mesh (10.2 mesh/cm) screens; 30,250 to 75,625 eggs (i.e., 1.0 to 2.5 liters of eggs) were placed in each tray. Daily 15-min formalin-drip treatments (1:600) were applied to minimize fungal growth (Wood 1974). Water temperatures (monitored daily) averaged 9.8°C and ranged from 7.0° to 14.0°C. Water flows were set at 19 liters/min. The developmental rate of some lots of eggs was manipulated to stagger the emergence of fry so that different lots for experiments could be obtained. After the fry reached the button-up stage, they were transferred to the start-up troughs to be reared or held until release.

Production Rearing

All start-up rearing was conducted in 442- x 54- x 28-cm Heath Techna start-up troughs with a 28-cm standpipe to maintain a usable volume of 660 liters. After more than 1 million fry were released, approximately 270,000 and 90,000 swim-up fry from Moose

Lake and the Goodpaster River, respectively, were held for rearing. Fry from the Moose Lake brood stock were divided into six troughs of 45,000 fry each (3.68 kg/m^3). Fry from the Goodpaster River brood stock were loaded into 2 troughs at densities of 45,000 fry each (3.48 kg/m^3).

Each trough was divided into three sections of 220 liters each. Tail and divider screens had 0.5-mm perforations. Fry were initially stocked in the lowest section of each trough; as maximal loading densities were achieved, the next upper divider screen was removed to increase the rearing area.

Initially, water flow was 19 liters/min in each trough, but this was adjusted to maintain a minimal dissolved-oxygen concentration of 7.0 mg/liter. Flows were kept low enough to prevent fry impingement against screens. Dissolved-oxygen concentrations were monitored weekly. The mean water temperature was increased from 13.5^{o}C to a maximum of 18.0^{o}C with 12,000-watt electrical immersion heaters.

Fry were initially fed Oregon Moist Pellet IV® (OMP) starter mash with a double-vitamin (DV) pack and extra vitamin C to provide a level of 3,200 mg/kg. The OMP-DV was ground with a mortar and pestle and sifted to obtain the required small particle size and to increase acceptability. Feed was dispensed at a rate of 4.9% body weight at 5-min intervals for 24-h/day with Loudon North Star® automatic feeders. Previous experiments indicated that Arctic grayling fry are photopositive and congregate in rearing troughs where the desired illumination is present. Consequently, fluorescent lights were installed under the feeder's spread bars and along the entire length of the trough to provide approximately 300 fc of light at the water surface 24 h/day.

Troughs were cleaned, and dead fry were enumerated and removed daily. Weights (g) and total lengths (mm) were measured when the fry emerged and every 14 days thereafter until release. When maximal densities were achieved in the troughs, the fingerlings were transferred into a 17.0- x 2.0- x 0.8-m concrete raceway where they were reared until their release. Fish were fed by automatic feeders every 5 min for 24-h/day.

Experimental Rearing

Our original objective was to conduct one trial of a warm-water rearing experiment using 18°C water temperature for the controls and 20°C for the test lots; however, outdated starter mash was inadvertently fed during the first 13 days of the experiment. When this was discovered, another trial of the experiment was repeated using the correct feed. Fry that had been previously designated for another experiment to measure the effects of light intensity were used for this experiment instead. Data from the first trial are included in this report but are not to be used for comparing growth or survival.

Trial #1:

A 32-day rearing experiment was designed using two troughs, while fish in 6 other troughs served as controls. Approximately 45,000 swim-up fry from the Moose Lake brood stock were stocked into each of the two experimental troughs and four of the control troughs. Two other control troughs contained 45,000 fry each from the Goodpaster River brood stock.

The mean water temperature was increased from 18.0°C to a maximum of 20°C with a 12,000-watt electrical immersion heater. The culture environment and all other techniques were identical to those for the production lots.

Trial #2:

The second trial of the scheduled 32-day rearing experiment used four troughs. Approximately 43,245 swim-up fry from the Moose

Lake brood stock were stocked into each of the two experimental and two control troughs.

The mean water temperature was increased from 18.0°C to a maximum of 20°C with a 12,000-watt electrical immersion heater. The mean water temperature during the first 14 days was 17.6°C for the control and 19.9°C for the test lots. On day 14, water flows were increased to maintain adequate dissolved-oxygen levels; unfortunately, the water temperatures decreased, and the mean temperatures for the entire 32 days were 15.6°C and 16.6°C for the control and test lots, respectively. Consequently, growth and survival data from only the first 13 days of the experiment are included. The culture environment and all other techniques were identical to those for the production lots.

Stocking

Fry were transported to stocking sites by placing a maximum of 19 liters of water and 30,000 fry into each plastic bag; oxygen was added, and the bags were sealed. The bags were placed into coolers, iced, and transported by plane or truck to various release sites. Most of the unfed fry were planted by Sport Fish Division biologists.

Fingerlings will be transported by hatchery personnel in a 1,900-liter fish-transport tank to the release site. Tank loadings of 0.16 kg of fish/liter of water will be used. In all releases, every effort will be made to minimize differences in water temperature between the transport tanks and the receiving water.

RESULTS

Brood-Stock Evaluation

A total of 10.2 million eggs were potentially available from the three brood stocks between 9 May and 7 June 1987 (Table 1). Among the wild brood stocks, the lowest number of eggs were available from the Goodpaster River; the highest number of eggs were available from Moose Lake. Brood-stock collection in the Goodpaster River was more time-consuming than at the other locations. Approximately 0.53 million eggs were potentially available from the hatchery brood stock of 145 adults, of which 71% were females. This egg take was obviously the most efficient and least time-consuming. Unfortunately, the Arctic grayling brood-stock evaluations at Butte Lake could not be completed during 1987.

Egg Take

The egg take at Moose Lake was conducted on 19 May. Approximately 2.6 million eggs were taken from 336 females. Average fecundity was 7,666 eggs/female. A male to female ratio of 1:1 was used. The Goodpaster River egg take was held on 19 May. Approximately 0.22 million eggs were taken from 49 females; the average fecundity was 4,494 eggs/female. Egg quality from both sources was excellent.

The hatchery brood stock spawned again in 1987, at 3 years of age. The average weight and length for males and females was 258 g and 28.9 cm and 273 g and 27.0 cm, respectively. Egg takes were conducted on 25 May, 28 May, and 3 June to obtain a total of 435,500 eggs. The average fecundity was 5,184 eggs/female. Eggs were again extremely small and averaged 62,000 eggs/liter.

Table 1. Characteristics of Arctic grayling brood stocks, 1987.

Brood stock	Spawning period	sex	Numbers of adults captured	Numbers of adults spawned	Average fecundity	Potential # eggs
Moose Lake	9 May to 19 May	F	1,162	336	7,666	8,908,000
		M	1,271	336		
			2,433	672		
Goodpaster R.	12 May to 26 May	F	178	49	4,494	800,000
		M	60	50		
			238	99		
Hatchery	25 May to 7 June	F	103	84	5,184	534,000
		M	42	42		
			145	126		
					TOTAL	10,242,000

Incubation

The water temperature within the incubators average 9.5°C throughout the 19-day incubation period, resulting in an accumulation of approximately 180 temperature units (TU). Survival rates for green eggs to fry was 59.5% from the Goodpaster River and 75.6% from Moose Lake. The survival rate of the eggs from the hatchery brood stock was essentially zero. Mortality of this lot of eggs began immediately, and within 5 days after fertilization, almost 100% mortality had occurred.

Production Rearing

Lot 1:

The fry in this production lot are the survivors from Trial #1 of the experimental rearing project. Survival rates include unexpectedly large mortalities during the experimental study. The estimated average survival rate from the fry-to-fingerling stage for the Moose Lake stock is 31.1% (Table 2). Growth rate of the fry from the Moose Lake stock is expected to be approximately .027 mm/TU/day. The growth rate of fry from the Goodpaster River is expected to be approximately .026 mm/TU/day.

Lot 2:

Only the Moose Lake stock was used for this lot, after the termination of Trial #2 of the experimental rearing project. The average survival rate from the fry-to-fingerling stage is expected to be 56.6%. Growth rate of fry is expected to be approximately .056 mm/TU/day with a food-conversion rate of 1.9:1.

Table 2. Arctic grayling survival rates and production, 1987.

Brood stock	Number of eggs: Taken	Number of eggs: Incubated	Emergent fry: Number emerged	Emergent fry: Survival (%)	Emergent fry: Number released	Emergent fry: Number reared	Forecasted no. for release	Projected survival (%) from fingerling	Expected release size (g)
Moose Lake	2,575,800[a/]	2,035,200	1,539,600	75.6	1,096,600	Lot 1: 270,000	114,000	42.2[b/]	4.0
						Lot 2: 173,000	98,000	56.6	4.0
Goodpaster R.	220,200	220,200	131,100	59.5	41,100	90,000	28,000	31.1	4.0-8.0
Hatchery	435,000	435,000	0	0.0	0				
TOTAL	3,231,500	2,690,400	1,670,500	62.1[c/]	1,137,700	533,000	240,000	45.0	

[a/] A total of 540,600 eyed eggs was shipped to Arizona Game and Fish Department and the University of Alaska, Fairbanks.

[b/] Includes lots from experiments with unusually poor survival.

[c/] Includes hatchery brood stock; average of wild brood stocks = 74.1%.

Experimental Rearing

Trial #1:

The average survival of Arctic grayling reared during Trail #1 for 13 days was 38.5% (Table 3). An estimated 30% of these fish, however, had scoliosis; and starvation and loss of equilibrium was occurring.

Trial #2:

The average survival rate of Arctic grayling reared at 19.9°C for 13 days was 68.4%, while the survival rate of those in the control lost averaged 58.2% (Table 4). There was very little difference in growth between the fish in the experimental and control lots; lengths, weights, and growth rates were similar (Table 5).

Stocking

Over 1,149,800 unfed Arctic grayling fry were stocked into 22 lakes statewide. A total of 540,600 green and eyed eggs were shipped to the Arizona Game and Fish Department and the University of Alaska, Fairbanks for research projects. In addition, 1,019 catchable-sized Arctic grayling were released into Sansing Lake. Fingerling Arctic grayling produced at Clear Hatchery are scheduled for release during late August each year.

DISCUSSION

Brood-Stock Evaluation and Egg Take

Brood-stock investigations during 1986 (Parks et al. 1986) and 1987 demonstrated that approximately 10 million Arctic grayling

Table 3. Survival rates of Arctic grayling fry reared at different water temperatures during a 13-day period (Trail #1), 1987.

Brood stock	Replicate	Treatment	Water temperature (C)	Starting rearing density Kg/m^3	Fry/liter	Number of fish survival Start	End	Rate (%)
Moose Lake	1-A	Control	17.7	3.68	205	45,000	13,274	29.5
Moose Lake	1-B	Control	17.3	3.68	205	45,000	27,530	61.2
Moose Lake	1-C	Control	18.5	3.68	205	45,000	23,057	51.2
Moose Lake	1-D	Control	17.8	3.68	205	45,000	29,257	65.0
Goodpaster R.	1-E	Control	18.1	3.48	205	45,000	16,672	37.1
Goodpaster R.	1-F	Control	17.2	3.48	205	45,000	18,160	40.4
MEAN								38.7
MEAN (all Controls)								47.4
Moose Lake	1-G	Warm Water	20.2	3.68	205	45,000	15,262	33.9
Moose Lake	1-H	Warm Water	19.2	3.68	205	45,000	19,374	43.1
MEAN								38.5

Table 4. Survival rates of Arctic grayling fry reared at different water temperatures for 13 days (Trial #2), 1987.

Brood stock	Replicate	Treatment	Water temperature (C)	Starting rearing density Kg/m^3	Starting rearing density Fry/liter	Number of fish survival Start	Number of fish survival End	Number of fish survival Rate (%)
Moose Lake	2-A	Control	17.8	3.54	197	43,245	27,218	62.9
Moose Lake	2-B	Control	17.5	3.54	197	43,245	31,962	73.9
MEAN			17.6					68.4
Moose Lake	2-C	Warm Water	20.3	3.54	197	43,245	27,239	63.0
Moose Lake	2-D	Warm Water	19.4	3.54	197	43,245	23,122	53.5
MEAN			19.9					58.2

Table 5. Growth of Arctic grayling fry reared at different water temperatures during a 32-day period (Trial #2), 1987.

Brood stock	Replicate	Treatment	Water temp (C)	Average weight (g) Start	Average weight (g) End	Average length (mm) Start	Average length (mm) End	Daily gain	Gain/TU/day
Moose Lake	2-A	Control	17.8	0.019	0.086	14.2	23.0	0.68	0.038
Moose Lake	2-B	Control	17.5	0.019	0.085	14.2	22.4	0.63	0.036
MEAN			17.6		0.086			0.66	0.037
Moose Lake	2-C	Warm Water	20.3	0.019	0.090	14.2	23.7	0.73	0.036
Moose Lake	2-D	Warm Water	19.4	0.019	0.070	14.2	22.1	0.61	0.031
MEAN			19.9		0.080			0.67	0.034

eggs are available annually from two wild brood stocks. Moose Lake will remain the primary source because of its large adult fish population, early spawning period, and excellent quality and quantity of eggs (*see* Table 1). This site, however, has poor access, requiring an approximate 5-km trip by all-terrain vehicles. Jack Lake, although not evaluated this year, will remain as the primary backup source because the run timing is 7 to 10 days later than Moose Lake, the population is large enough to meet the 2 million egg-take goal, and there is an excellent quality and quantity of eggs. Access to this site is excellent, but the trapping operation is hampered by ice and high water because Lower Twin Lake breakup occurs during the egg take. An egg take on the Goodpaster River is the most likely to fail because of its inaccessibility and the difficult adult-capture conditions during the breakup period. The adult population size is small, and a potential limit of 400,000 eggs makes this source a poor candidate for a primary egg-take site. This brood stock is very important, however, as an egg-take source for Arctic grayling stocking projects in the Yukon River drainage.

Only a minor deviation from the objectives of the brood-stock evaluation plan was made during 1987. The planned evaluation of Butte Lake brood stock did not occur because the timing interfered with the warm-water-rearing experiment (Trial #2).

Arctic grayling hatchery brood stock (BY-84 from Jack Lake) matured and spawned in 1986 at 2 years of age and again this year at 3 years of age. As predicted, both egg size and average fecundity increased with larger and older females (Rounsefell 1957; Buss and McCreary 1960; Gall 1969). Female average weight and length increased from 187 g and 24.5 cm to 273 g and 27.0 cm, respectively. Fecundity increased from 2,648 eggs/female to 5,184 eggs/female, which is similar to that of the parent stock (Table 6). Although egg size increased (17.1%) from 74,781 to 62,000 eggs/liter, the size was less than half that of the parent stock. Survival to the eyed-egg stage remained essentially zero.

Table 6. Characteristics of the Arctic grayling brood stock at Clear Hatchery.

Stock	Origin	Spawning age	Average fecundity	Average egg size (No./liter)
Jack Lake	Parent	4(+)	5,026	26,000
Hatchery	BY 1984	2	2,648	74,781
Hatchery	BY 1984	3	5,184	62,000

Gall (1974) reported that the percentage of eggs reaching eyed stage increased as egg size increased in lots of hatchery-reared rainbow trout, *Salmo gairdneri*; we expected similar results to occur for the Clear Hatchery Arctic grayling brood stock, but unfortunately, this was not the case. Most likely, the diet used for the Arctic grayling brood stock was incomplete. Thus poor nutrition probably led to the failure of the embryos to develop longer than 5 days after fertilization. During FY 1988, the brood stock will be divided into two experimental lots to evaluate the effects of different commercial rainbow trout brood-stock diets on egg survival. One lot of fish will be fed Silver Cup®; the other, Rangens®.

Postspawning mortality has reduced the hatchery's brood-stock (BY 1984 Jack Lake) Arctic grayling population from 145 to 50 fish. Most of the mortality resulted from *Saprolegnia* infections after spawning and other handling. With so few fish remaining in this group, they were released, and the project was terminated. The BY-1986 Moose Lake brood stock will replace this group; this stock will first reach maturity and spawn in May 1988.

Production and Experimental Rearing

Some of the most important factors affecting fry survival in the hatchery include the water temperature, diet, timing of feeding, food density, fish density, and light intensity. Arctic grayling fry reared at 18°C for 13 days water survived better (68.4%) than those reared in 20°C, but growth was only slightly greater for fish reared at 18°C than 20°C. With the results from last year's study (Parks et al. 1986), we have concluded that optimal growth and survival can be attained when Arctic grayling fry are reared at a water temperature of 18°C. When Arctic grayling are reared at 18°C, a fry-to-fingerling survival rate of approximately 65% can be reasonably expected. With a 75% survival rate from green egg to emergence, the overall survival rate from green egg to fingerling is nearly 50%.

Arctic grayling fry are photopositive, and they move to areas of the trough where the preferred illumination is present. If lighting for newly ponded fry is inadequate, the fry tend to settle on the bottom until crowding causes suffocation. Although we did not conduct experiments to compare different levels of light intensity, our lighting level of 300 fc appears to have been adequate.

The nutritional requirements of Arctic grayling, like those of many other cold-water fishes, are poorly known. Arctic grayling fry, however, will die if they do not start feeding within the first 10 to 14 days at 18^{o}C. Those fry that start feeding, however, appear to eat and grow well (at least through the fingerling stage) on the high protein diet OMP IV-DV. Early adaptation to this diet is essential to reduce starvation during the prefingerling stage of intensive culture. Fry should be ponded as soon as they are able to swim to the surface. Since the first 8 days after swimup are the most critical, fry should be fed in excess at least once every 5 min for 24 h/day.

The two apparent causes of mortality for Trail #1 of the Rearing Experiment and Production Lot #1 were (1) starvation and (2) a vitamin-C deficiency that caused scoliosis, resulting from the accidental feeding of outdated starter mash. During Trial #2, when properly dated feed was used, mortality caused by scoliosis was estimated at less than 1%. During the first 10 days, the approximate 37% mortality was attributed to starvation; these fish did not initiate feeding.

Results from this year's and previous years' diet experiments suggest that Arctic grayling require extra vitamin C in their diet. It is important to provide fresh lots of feed, because vitamin C deteriorates rapidly during storage. We have not determined, however, if vitamin C is lost through our grinding and sieving process that reduces particle size or if Arctic grayling fry require more vitamin C than other species. This year's diet appeared to meet the nutritional needs of our fry, and we will continue to use it in future years.

We anticipate that Arctic grayling fingerling production and survival will exceed the original production goals. Sport Fish Division originally requested approximately 210,000 fingerlings for stocking; the projected production of 240,000 fingerlings will be 14% greater than the amount requested. The expected survival rate from fry to fingerling is 50%; the survival rate will probably be 45%. If the mortality that resulted from feeding oudated feed is excluded, the survival rate would be 57% from fry to fingerling.

CONCLUSIONS

A total of 2.8 million Arctic grayling eggs were taken from fish at Moose Lake and the Goodpaster River in 1987. The Jack Lake brood stock will be the primary backup egg-take site if the Moose Lake egg take fails; the Tahneta Lake stock will be the secondary backup location. A total of 1,137,700 fry was released into many lakes and streams, and a projected total of 240,000 fingerlings (between 4.0 and 8.0 g) is expected to be released into over 20 lakes and streams during August 1987.

Experimental Arctic grayling cultural techniques that have been developed at Clear Hatchery for several years have been successful. We have learned that (1) eggs should be loaded into incubator trays at a rate of 1.0-2.5 liters of eggs/tray; (2) Arctic grayling eggs should be incubated in trays with large-mesh screens, but these should be transferred to trays with fine-mesh screens before hatching; (3) rearing density should be approximately 200 fry/liter; and (4) light intensity should be 300 fc evenly distributed for 24 h/day.

Excellent growth of fry can be achieved with finely ground OMP IV-DV starter mash with extra vitamin C that is provided at 5-min intervals for 24 h/day. The most critical period for survival of Arctic grayling fry is the initiation of feeding during the first 10-14 days of rearing.

Arctic grayling are annual spawners, and all BY-1984 Jack Lake adults spawned (245 fish) in 1987 produced 435,500 eggs. Unfortunately, all eggs died within 5 days of fertilization. Greater adult size increased egg size and female fecundity, but apparently, the brood-stock diet was unable to supply adequate nutrition for the spawners to produce viable gametes.

RECOMMENDATIONS

Brood-Stock Evaluation

1) Continue maximal growth rate for the BY-1986 Moose Lake hatchery brood stock. Adjust water temperature and photoperiod according to their natural environment. Divide this stock into two tanks and feed Silver Cup brood-stock diet to one and Rangens brood-stock diet to the other to determine if either diet will increase egg survival.

2) Randomly select 1,000 BY-1987 Moose Lake Arctic grayling for additional hatchery brood stock.

Egg Take

1) Continue to use Moose Lake as the primary brood stock for spawning operations.

2) Continue Goodpaster River brood stock for Yukon River drainage enhancement projects.

3) Use Jack Lake and Tahneta Lake brood stocks as primary backups.

4) Evaluate Butte Lake for additional backup brood stock.

5) Calculate the egg-take goal for Moose Lake with planning assumptions of 75% egg-to-fry and 65% fry-to-fingerling survival rates.

<u>Incubation</u>

1) Load incubators with densities of 1.0-2.5 liters of eggs/tray.

2) Treat eggs daily with formalin.

3) Incubate eggs in trays with large-mesh screens, but before hatching, transfer them to trays with fine-mesh screens.

<u>Rearing</u>

1) Initial fry-rearing density should be 200 fish/liter.

2) Feed OMP IV-DV with 3,200 mg vitamin C/kg every 5 min for 24 h/day.

3) Provide even-lighting conditions over the entire trough at approximately 300 fc for 24 h/day at water surface.

4) Provide 18°C water during the first 14 days of rearing.

5) Conduct rearing experiment to evaluate Biodiet®.

6) Conduct light-intensity experiment using lighting levels of 75, 150, and 225 fc.

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REFERENCES

Buss, K. and R. McCreary. 1960. A comparison of egg production of hatchery-reared brook, brown, and rainbow trout. Prog. Fish. Cult. 22: 7-10.

Gall, G. A. E. 1969. Quantitative inheritance and environmental response of rainbow trout. In: O. W. Neuhaus and J. E. Halver (Editors), Fish in Research. Academic Press. New York, NY. pp. 117-184.

Gall, G. A. E. 1974. Influence of size of eggs and age of female on hatchability and growth in rainbow trout. Calif. Fish and Game. 60: 26-35.

Lord, R. F. 1932. Notes on Montana graylings at the Pittsford Vt., Experimental Trout Hatchery. Trans. Amer. Fish. Soc: pp. 171-178.

Parks, D., Burke, T., and D. Bee. 1986. Arctic grayling culture. Federal Aid in Sport Fish Restoration. F-23-R. 1(5). 28 pp.

Rounsefell, G. A. 1957. Fecundity of North American salmonidae. U. S. Dept. Int. Fish Wildlife. Serv. Bull. 122: 451-465.

Wood, J. W. 1974. Diseases of Pacific salmon, their prevention and treatment. State of Washington. Department of Fisheries. 82 pp.