Salmon Genetics Research Program

Annual Report 1986/87

Government of Canada
Fisheries and Oceans

Gouvernement du Canada
Pêches et Océans

ATLANTIC SALMON FEDERATION
FEDERATION DU SAUMON ATLANTIQUE

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Gilbert Van Ryckevorsel

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CONTENTS

TABLES

FIGURES

PICTURES

PREFACE

The Atlantic Salmon Federation is dedicated to the preservation and wise management of the Atlantic salmon and its habitat, seeking to meet these goals through programs in research, education, management and international cooperation. In the area of research, the Federation's most ambitious undertaking is the Salmon Genetics Research Program, begun in 1974.

The Salmon Genetics Research Program, conducted at the Federation's Salmon Research Center in St. Andrews, New Brunswick, is a joint research program of the Canada Department of Fisheries and Oceans and the Atlantic Salmon Federation. It is an excellent example of private-government cooperation, demonstrating the tangible benefits that can accrue to resource management when private and public sectors work in concert toward long-term goals.

The mandate of the Salmon Genetics Research Program is applied genetics research in direct benefit of Atlantic salmon management. The results of its unique studies are proving to have positive implications for the resource and the resource users — from angler to aquaculturist. The Federation joins the Canada Department of Fisheries and Oceans in taking pride in these achievements.

This report highlights the scientific activities of the Salmon Genetics Research Program for the period April 1, 1986 to March 31, 1987.

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OVERVIEW

The Salmon Genetics Research Program, after 13 years of operation, continues to produce results of interest to the angler, commercial fisheries and the new, cage-culture industry. Specifically, the results of the program have demonstrated genetic variation for many traits of interest to these various users of the technology. The development of selection and mating procedures to fit the Atlantic salmon has allowed for application of breeding techniques to problems in growth and development.

The differences between river stocks with respect to such traits as ability to become sexually mature in one or more than one year at sea (grilse versus salmon) has enabled the synthesis of four strains (A, B, C and D). Strains A and B have a much higher incidence of grilse than do Strains C and D. Experiments have demonstrated that growth is responding to selection. Grilse appear to have faster early growth than salmon prior to the age at which grisle become sexually mature. Therefore, the manipulation of both growth and age at sexual maturity seems possible. Consequently, the development of fish to fit specific requirements of size for anglers and productivity for cage culturists seems feasible.

The application of controlled day lengths, to regulate growth and smolt development in the freshwater stages, and the use of synchronization of reproduction by hormone treatment, are examples of environmental control that can be coupled with the application of genetics. Similarly, the finding of a genetic basis for resistance to at least one disease (furunculosis) augers well for the enhancement of disease prevention through breeding technology.

The research to date has produced some exciting results and, although problems still exist, the future for the application of genetics and breeding techology in the Atlantic salmon is promising.

INTRODUCTION

The improvement of plants and animals has involved the selection of superior parents for many centuries. The development of refined selection techniques, based on the sciences of genetics and statistics, has greatly enhanced gains from selection. Mating systems have had to be considered hand-in-hand with selection procedures, particularly in minimizing inbreeding. Results of research over the last 15 years in Europe and North America indicate that there is a great potential for the application of these breeding techniques in the Atlantic salmon.

The Salmon Genetics Research Program (SGRP) is a long-term project aimed at the application of genetics to the Atlantic Salmon *(Salmo salar)*. The Atlantic Salmon Federation (ASF) conducts the research under contract with the Department of Fisheries and Oceans of Canada (DFO) in the Federation's Salmon Research Centre (SRC) near St. Andrews, New Brunswick, Canada.

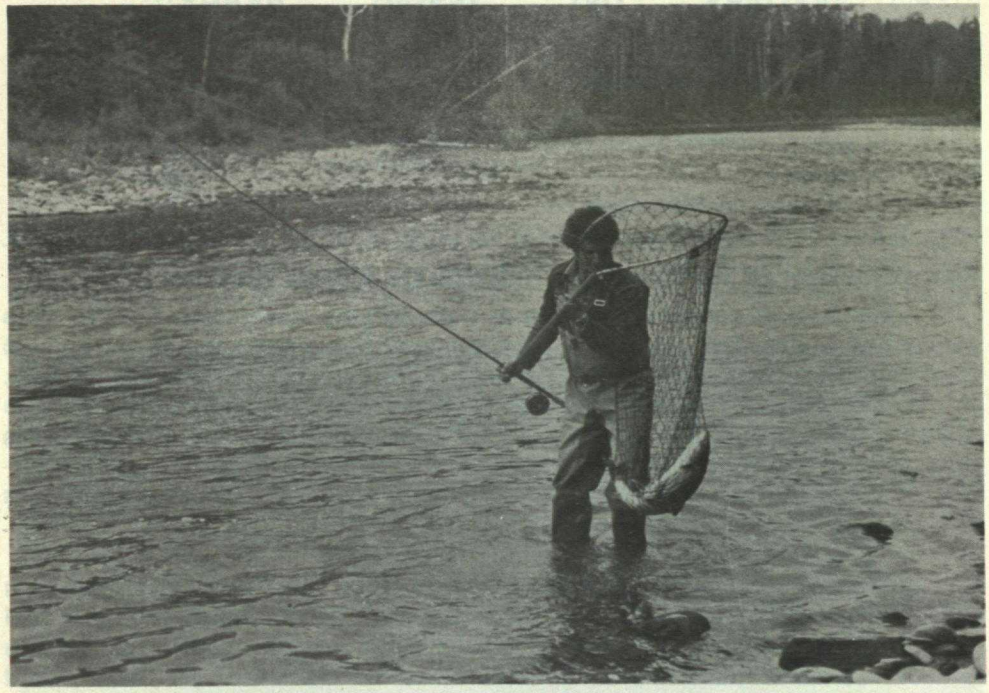
The third year of a five-year contract for the program has been completed, where the current SGRP contract was initiated in 1984 and was preceded by two previous five-year contracts.

The initial phases of the research involved the study of stocks from eight different New Brunswick rivers. Crosses and pure matings of the various stocks were tested, in a sea ranching environment, with respect to ability to return from sea after one sea winter (grilse) or after more than one sea winter (salmon). A sea-cage salmon industry, initiated in 1978 in the Bay of Fundy near the SRC, has grown rapidly to a projected 50 million dollar industry by 1990. Collaboration with this aspect of salmon culture has enhanced the efforts of the SGRP in two ways, firstly in the holding of gene pools involved in sea ranching and, secondly in broadening the objectives to deal with problems experienced by cage culturists.

THE APPLICATION OF SELECTION AND MATING TECHNIQUES IN THE SGRP

Diversity of river stocks

Early studies in the SGRP and allied programs indicated that stocks from different rivers were variable with respect to many traits, such as: ability to return from sea, growth rate, age at sexual maturation as grilse or as multi-sea-winter salmon, incidence of mature male parr, repeat spawning and ability to smoltify after one year. This tremendous diversity suggested the possibility of forming gene pools or strains to fit specific objectives in both sea ranching and sea-cage rearing. Early studies are showing that much of this variation is heritable and therefore amenable to the application of selection and mating procedures.



Picture 1. SGRP research has shown a genetic basis for the diversity of river stocks as appreciated by the angler. (Courtesy ASF)

Variation within stocks

The different river stocks appear to have a high degree of variation for a number of traits. The coefficient of variation is a statistic which reflects the variance as a percentage of the mean. The estimates of this statistic in Table 1 reveal that there is a great deal of variation in most traits. Length is less variable than weight but is highly correlated with it. Therefore, length is often the trait used to indicate size because it can be more easily measured under adverse conditions, as often encountered in certain aquaculture situations.

The estimates (Table 1) are in line with those of Gjedrem (Aquacult. 6:1975, 23-29) who found much higher degrees of variation in salmonids than in terrestrial species such as cattle, sheep and swine. Since variation is a requirement for selection, probabilties are good for the attainment of gains in desirable attributes of the Atlantic salmon.

Table 1. Estimates of coefficients of variation for certain traits in SGRP strains.

Trait	Coefficient of variation (%)
Number of eggs per female	28.0
Egg volume per female at eyed stage	67.0
Number of parr per female	81.7
Weight — fry	31.7
— parr	20.8
— smolt	47.4
— 10 mos. in sea cages	30.1
Length — fry	10.2
— parr	8.4
— smolt	36.5
— 10 mos. in sea cages	8.0

Identification of families and individuals within families

Members of families with one or both parents in common tend to have similar genes. This fact makes the partitioning of the genetic and environmental contributions to the variation of traits, such as weight or length, feasible. Hence, the identification of families with specific marks or tags becomes essential in a breeding program. Furthermore, the identification of individuals within families becomes important with respect to selecting candidates whose level of performance is superior to that of their family average, particularly in the case of traits that must be measured at different times.

The identification of up to 48 families can be readily accomplished with the use of a combination of brands and a single fin clip. Brands above the lateral line are more readable than those below. With three positions on each side above the lateral line (Figure 1) and four directions for the pointing of a V brand (Figure 2), 24 families can be identified. Using the presence or absence of a fin clip, such as the adipose, to give a multiplier of two, 48 families can have separate marks. This is a sufficient number of families for SGRP control lines. However, the identification of families in a selected line, randomized into tanks with control families, requires extra marks such as the clipping of pelvic fins. The clipping of pelvic fins on fry has been only partially satisfactory where some regeneration of fins leads to confusion.

The marking of a large number of families, or the identification of individuals within a family, requires detailed numbering systems. The use of poultry wing tags in the operculum of cage-reared salmon has been only partially satisfactory, due to the loss of the tags. Modified Monel metal tags, similar to

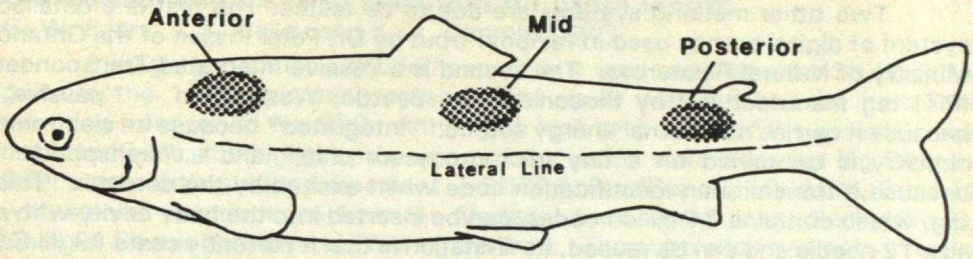


Figure 1. Three positions above the lateral line on each side of a fish increases the number of families that can be identified.

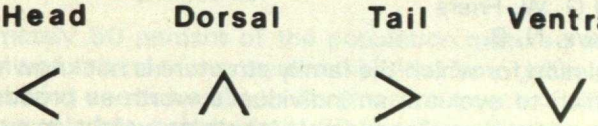
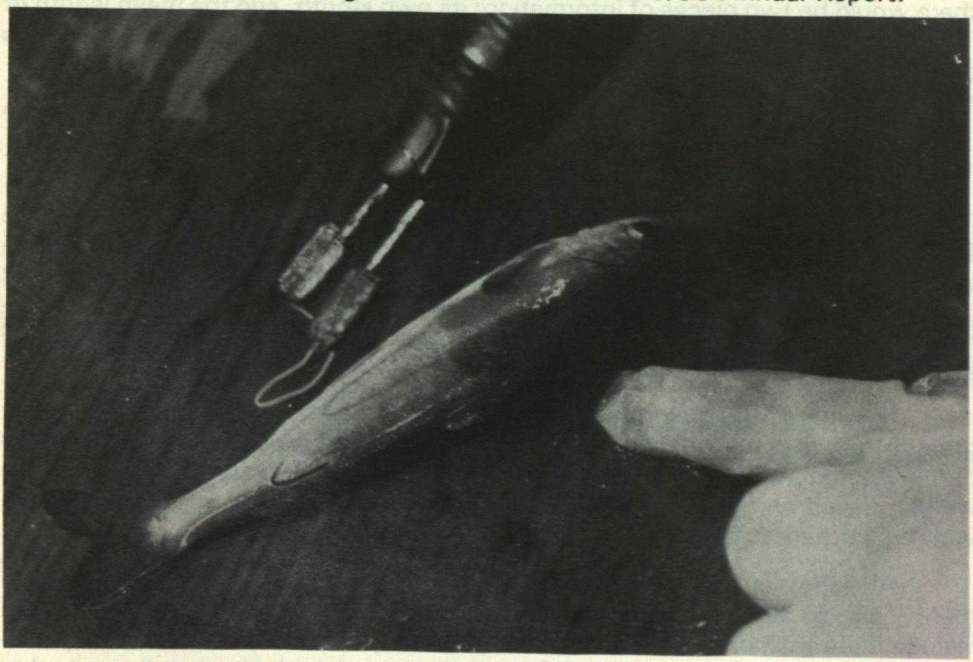


Figure 2: Four directions of a V brand can be applied in each branding position.

poultry wing tags, are currently being compared to the poultry wing tags in cage-reared salmon. Similarly, the use of panjet dye marks in the fins has given satisfactory results for Dr. Gary Newkirk of Dalhousie University and will be further tested in the SGRP in light of results in the 1985/86 Annual Report.



Picture 2. The use of hot brands allows the identification of fish from different families. (Courtesy ASF)

Two other marking systems are due to be tested. The first is a detailed system of digital brands used in rainbow trout by Dr. Peter Ihssen of the Ontario Ministry of Natural Resources. The second is a Passive Integrated Transponder (PIT) tag manufactured by Biosonics Inc., Seattle, Washington — "passive" because it carries no internal energy source; "integrated" because its electronic circuitry is contained on a tiny microprocessor chip; and a "transponder" because it transmits an identification code when excited by the detector. This tag, which contains 34 billion codes, can be inserted into the body cavity with a size 12 needle and can be reused. Its limitation is that it currently costs $9 (U.S.) per unit in orders of 500 or more.

Supplementing information on individuals with family performance data

J. K. Bailey and G. W. Friars
SRC, St. Andrews, N. B.

In a population for which the family structure is not known, the only information with which to evaluate an individual's worth as broodstock (breeding value) is its own phenotype, for example length or weight. In such populations, mass selection (choosing the highest ranking fish) is the single option available for selecting the 'best' parents for the next generation. When families are known and identifiable, measurements from relatives provide an additional source of input for the evaluation process.

For example, a typical strategy for domestic salmon might be to measure the length of each fish at some time, such as harvest. Thus, for each salmon there would be two pieces of information; its own length, and the mean length of its family. By assigning different relative weights to these two sources, various options for selecting broodstock emerge. These include:

a. family selection
b. within-family selection and
c. combination of a and b, above, or index selection.

In family selection, zero weight is given to individual length, and entire families are selected strictly on the basis of family means. The converse occurs in within-family selection. Zero weight is afforded the family means and the longest individuals in each family are selected. Index selection uses both pieces of information and the relative weights assigned to each are dependent upon family size and the heritability for length.

In general, the weight assigned to mean family length would be relatively greater than that for individual length. This occurs because family averages are better estimators of breeding value, particularly where heritabilities are low. The weight placed on family means tends to increase with family size and decrease with higher heritabilities.

An index is the most efficient method of selecting broodstock and, in theory, should lead to the most rapid genetic gain. Indexes can be expanded to include more than one trait and information from relatives other than sibs. Selection indexes are proposed to identify superior broodstock in select lines used in the SGRP.

Correlated responses to selection for grilse length

G. W. Friars, J. K. Bailey and K. A. Coombs, SRC

A single generation selection experiment was commenced with Strain A grilse in the 1985 spawning season. This strain was synthesized from fish returning from sea to the SRC. Although a high proportion of the parents were not identifiable, the highest proportion of the genes were from the Big Salmon River stock (estimated at 54 percent — SGRP Annual Report, 1985/86, Table 1) with smaller contributions from the Magaguadavic, Saint John, Rocky Brook, Sevogle, Dennis Stream and Waweig systems. The population had not yet been subjected to random mating to allow an approach to genetic equilibrium (mixing of genes), following systematic crosses made in the two previous generations. Consequently, the experiment has some shortcomings but will serve as a pilot run for future selection experiments.

Approximately 50 percent of the population matured as grilse. Hence, both the control and selected lines were established from grilse. The control line was started by taking one son and one daughter from each of 50 full-sib families that had been sampled at random from 98 families. Single-pair matings were made at random, with the avoidance of full-sib matings, to form a control line. The remaining 2333 fish were ranked according to fork length. The top ranking males and females were selected by truncation or mass selection (Figure 3). Fifty-six single-pair matings, involving the longest males and females were made. This yielded a selection differential of 1.52 standard deviations (difference between the mean of the overall population and that of the selected parents) and involved mating procedures similar to those used for the control line.

Comparisons of the control and selected lines for several traits in 1986/87 reveal interesting results (Table 2). The selected families in contrast to the controls produced more eggs. The eggs were larger in size and survivability through the egg and fry stages was superior.

Table 2. Egg production, egg size, survival and fry from control and selected lines of grilse

Trait	Line	
	Control	Selected
Number of eggs per female	4430	5744
Egg size at start (mm^3)	8.95	9.97
Survivability to eyed egg stage (%)	35.6	48.6
Survivability to fry stage (%)	22.7	32.10
Number of parr per family (excluding zeros)	1270	2135
Fry weight (g)	2.07	1.99 N.S.[2]
Fry weight corrected for family size (g)[1]	1.97	2.06
Fry length (cm)	5.59	5.57 N.S.
Fry length corrected for family size (cm)	5.51	5.63 N.S.

1. Corrections for family size employed a covariate for the number of fry per family in a 1 m diameter tank.
2. N.S. — differences between the control and selected lines were non-significant ($P < .05$). All other such differences were significant ($P < .05$).

The control families had longer mean fry fork lengths and weights of parr in comparison to selected line counterparts, a trend contrary to the direction of selection. However, examination revealed negative correlations between family size, as it affects density with a single family per tank, and fry weight or fork length. A covariance correction for family size, where single families were reared in separate 1 m diameter tanks, allowed comparisons of the fry from the control and selected lines at a constant family size. After this adjustment, the selected-line fry were larger than controls. Although these differences were not significant ($P < .05$)[1], this emphasizes the need to standardize density per tank at an early stage.

The numbers of fish were standardized to approximately 3250 per 25-ft. diameter outside rearing tank. Through the use of fin clip identification, three control and three selected line families were placed in each tank. Each such set of six families was replicated between a fibreglass and a concrete tank. Comparison of the control and selected line families at the January-to-March stage, following six to eight months of rearing in the outside tanks, are shown in Table 3.

Smolts are arbitrarily defined as fish greater than or equal to 13 cm when measured in January-March, approximately 2-3 months before the smoltification process reaches its peak. The percentage of smolts for the control and selected lines (Table 3) was 62.1 and 69.5 respectively, a significant ($P < .05$) difference of 7.4 percent. This correlated response in smoltification rate, when selection was applied to grilse fork length, indicates that development rate to the smolt stage was better for the larger parents. Hence, an enhancement of smoltification appears to be positively related with growth rate to the grilse stage in terms of genetic influence.

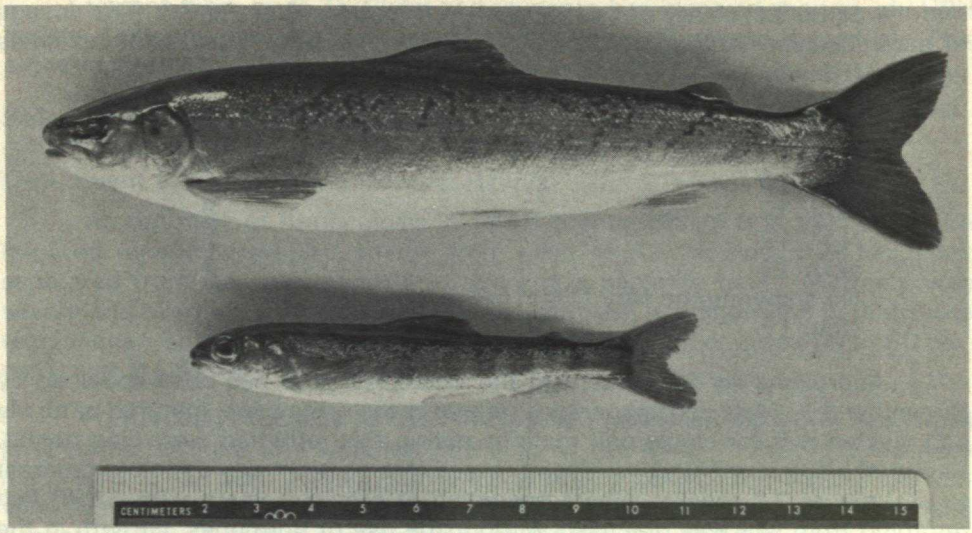
Table 3. Growth and maturity traits of control and selected line fish.

Trait	Line	
	Control	Selected
Proportion of smolts (> 13 cm)	62.1*	69.5
Mean length of parr (< 13 cm)	11.0	11.2
Mean length of smolts (> 13 cm)	16.2	16.5
Percentage of male parr [1]	75.6	63.2
Percentage of male smolts	42.8	44.3

* Difference between control and selected was significant ($P < .05$).

1. The percentage of males was determined by dissecting 15 parr and 15 smolt from a control and select family in each of 22 tanks and scoring for the presence or absence of ovaries or testicular vestiges.

1 The probabilities of type 1 errors are expressed as $P < .01$ or $P < .05$ in this report since F tests had to be synthesized for the mixed models and compared to tables of F distributions.



Picture 3. Smolts are generally longer and more silvery than parr. (Courtesy ASF)

The biological mechanism for the increased proportion of smolts is probably a complex phenomenon. However, the larger egg size in the selected versus control females could have had a bearing on this result, as was the case for fry size when density in the tanks was corrected statistically. In practical terms, genes which give good growth to the grilse stage appear to also increase rate of smoltification.

The slight advantages for the select over the control in parr and smolt lengths were not significant. This is not surprising since the main differences in size have been accounted for by the proportions above and below 13 cm fork length, the cut-off point for the smolt-parr classification in this study. In general, the frequency of fish near the 13 cm point was low, indicating fairly sharp bimodality in most families.

The proportion of males is much higher ($P < .01$) in parr than smolts and there is a predominance of females in the smolts (Table 3). There is a difference, with respect to more males in parr than smolts (i.e. those > 13 cm) of 18.9 percent in the selected line, compared to 32.8 percent in the control line. This suggests that a portion of the increased percentage of smolts in the selected line is due to more males reaching the length of 13 cm or better.

Synchronization of spawning

SRC Staff and B. D. Glebe, Huntsman Marine Laboratory

The procurement of milt and eggs from a large number of broodstock simultaneously is a requirement for the implementation of mating systems that produce a large number of families similar in age. Research on salmonids with lutenizing hormone-releasing hormone (LHRH) has advanced the overall spawning season in the SGRP. For example in 1986, the LHRH analogue was injected

into the peritoneal cavity of the females on November 3rd and 7th. The dosage of each injection was approximately .02 mg/kg of fish. The spawning times were as follows:

Date	Number of females
Nov. 9	10
Nov. 10	19
Nov. 11	9
Nov. 12	2
Nov. 13	4
No spawning on Nov. 14, 15 and 16	
Nov. 17	11

Approximately 90 percent of the treated females had been spawned by November 17. Male contemporaries, reared in the same cage, matured naturally and yielded milt for single pair matings during this retracted spawning period. Hence, the spawning time was compressed into an eight-day period in contrast to as long as 12 weeks, where spawning in previous years with SGRP fish returning from sea was practised without the use of hormones. Growth in the progeny can now be analyzed with fewer age complications than before. Consequently, LHRH hormone appears to be a practical breeding tool in Atlantic salmon.

Picture 4. Egg release from a large number of females at one time is accomplished with hormone treatment. (Courtesy ASF)

Recent work by B. D. Glebe and students has involved the use of LHRH pellets. Only one injection is required and the hormone release is gradual. This procedure may be used in SGRP operations in 1987.

Selection for disease resistance

G. W. Friars and J. K. Bailey, SRC and G. Olivier
Department of Fisheries and Oceans, Halifax

An outbreak of furunculosis in 1984 infected Strain B at the SRC. One hundred randomly-sampled smolts from each of 42 families, that had been separated from the total population, were in a separate tank. Mortality was severe and eventually the population was destroyed in compliance with disease regulations. The survivability at the time of disposal ranged from 18 to 98 percent over the 42 families.

Fortuitously, full sibs to the infected fish had been placed in sea cages prior to the outbreak and were not affected. In November 1985, matings were made among fish from the high survival and among individuals from the low survival families of progeny. The progeny from these matings were nieces and nephews of the fish that succumbed to the disease in 1984.

Samples of these nieces and nephews were shipped from the SRC to Dr. G. Olivier, Department of Fisheries (DFO), Halifax. Representatives of the different families were subjected to three methods of challenge with the furunculosis organism *(Aeromonas salmonicida),* namely:

1. Infection in a bath
2. Cohabitation with infected fish.
3. Injection with the organism.

The results for the different families varied from one challenge method to another. Although there was not an absolute division between the high and low resistance families with respect to survivability, there was a tendency for the highly resistant families to survive better. The encouraging aspect of the study was that two of the progeny families, from the highly resistant parent families, showed a high degree of survivability with all three methods of challenge.

Reconditioned grilse and two-sea-year-maiden spawners were available to repeat the study in 1986. They will be ready for challenge in 1987. The discovery of apparent genetic resistance to furunculosis is exciting and points to the possibility of developing strains of fish with disease resistance, an area of breeding that has contributed greatly to the poultry industry. The applicability of genetic resistance to other diseases of Atlantic salmon is an area that needs to be explored.

Sex reversal of females

G. W. Friars and K. A. Coombs, SRC
B. D. Glebe, Huntsman Marine Laboratory

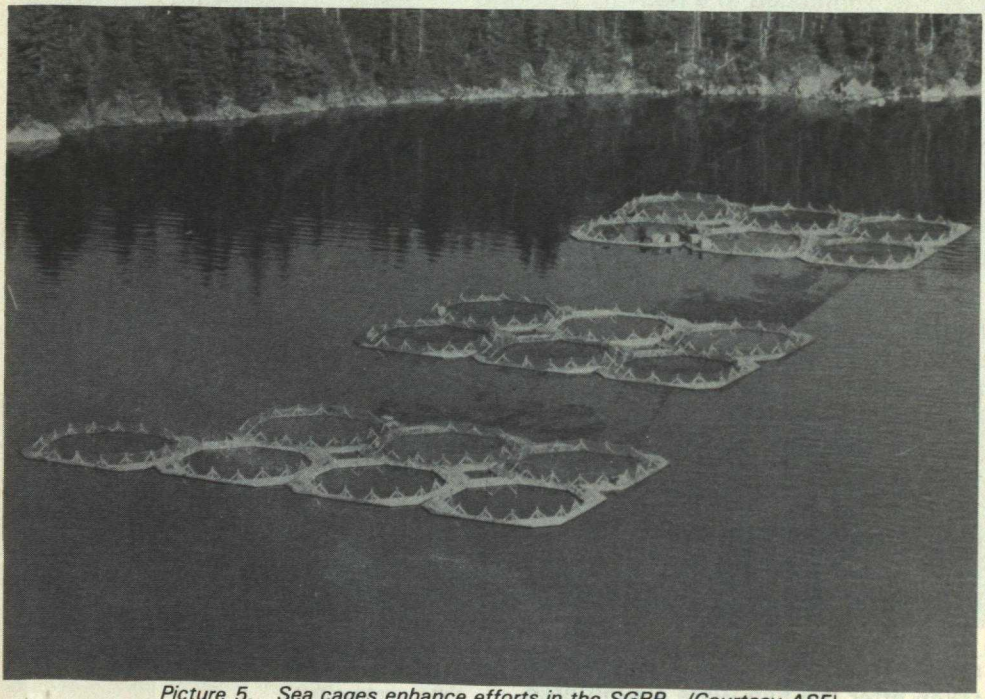
Previous work by B. D. Glebe had shown success in reversing females to males. These males had developed testes but no sperm ducts and hence milt was taken after the fish were slaughtered.

Approximately 2000 first feeding fry were given food with 3 parts per million of methyl testosterone for 57 days in 1986 at the SRC. Dissection of 123 of these fish revealed no ovaries and the treatment was considered successful.

The reversed females should carry two X sex chromosomes as opposed to one X and one Y in the case of conventional males. Fertilizaion with milt that contains only X chromosomes should produce all female progeny. This phenomenon has a real advantage where a higher incidence of grilse in males as opposed to females is undesirable in sea-cage culture. Furthermore, the production of sterile triphoid fish, through heat or other forms of shock to the eggs, can be more readily accomplished with all female populations. This mating procedure will be tried on both control and selected line fish, using the milt from the reversed females, in the next generation. The advantages of selection in a normal diploid in contrast to a triploid background can then be evaluated. Triploids do not become sexually mature and such sterility is desirable in aquaculture — sterile fish do not take energy away from meat production to meet reproductive requirements, and alleviate the fears of cage escapees mixing with the gene pools of natural stocks.

SEA-CAGE REARING IN CONJUNCTION WITH SEA RANCHING

Anglers, commercial fishermen and the Indian fishery, were the principal users of Atlantic salmon technology when the SGRP was initiated in 1974. In 1978, the commercial rearing of salmon in cages began in the West Isles region



Picture 5. Sea cages enhance efforts in the SGRP. (Courtesy ASF)

of the Bay of Fundy. The cage industry has grown very rapidly and is projected to produce 50 million dollars worth of fish for market in 1990. The emergence of this new industry has enhanced the SGRP in two principal ways namely, exchange and development of new technology and the holding of gene pools for research.

Involvement of the various SGRP strains in sea ranching and cage rearing.

The previous mention of Strains A and B, with respect to selection for grilse length and furunculosis resistance respectively, contained a description of the formation of control lines. Cage rearing, in cooperation with Fundy Aquaculture at Grand Manan, has enabled the procurement of a son and a daughter from each full-sib family in order to derive a random sample of genes for controls, a feat that would have been impossible using only returns in a sea-ranching scenario. Where selection in these lines is proposed to be based on sea-ranch returns, commencing in 1989, the procurement of genes from full brothers and sisters in cages may be necessary. Hence, cage rearing has increased the possibility of developing sea-ranched strains.

Early work with sea cages indicated that Big Salmon River fish had a higher incidence of grilse than Saint John River fish. Where the market desired fish in the 6-9 pound live weight category, two sea-winters of growth were required. The grilse were undesirable in this respect because of the fact that sexual maturity after one sea-winter retarded growth and decreased flesh quality. Hence, the Saint John River fish, represented by Strains C and D in the SGRP, became the principal stock used in cage culture.

Grilse versus salmon in sea cages

J. K. Bailey and G. W. Friars, SRC

Though traditionally avoided by commercial growers, stocks which produce large proportions of grilse are beginning to spark new interest for commercial cage culture. Recent cage studies by the SGRP and others have suggested that grilse tend to grow more rapidly and efficiently than salmon; certainly until their gonads begin to develop.

Samples of fish from SGRP Strains A and B were transferred to sea cages in 1984 as 2+ and 1+ smolts, respectively. Designated as grilse strains, both contain high proportions of Big Salmon R. genes and, when grown in sea cages, produce about 50% grilse. Smolt length averaged nearly 20 cm and approximately 15 cm for Strains A and B, respectively. In 1985, a similar sample of 1+ smolts from SGRP Strain C was transferred to the same marine site (Fundy Aquaculture, Dark Harbour, Grand Manan, N.B.). Strain C is referred to as a salmon strain. It contains 100% Saint John River stock and yields very few grilse. On average, the 1+ smolts of Strain C were about 15.5 cm long.

In March 1985, each fish in Strain A and B was measured, identified and marked with a numbered aluminum chicken wing tag which was clamped through the opercular bone. The fish were measured again in August and November. The Strain C fish were sampled only once in November, 1986 at which time they were also tagged.

By November of each year, maturation as grilse was apparent. Approximately 50% of the fish in Strains A and B (50.2% and 52.2%, respectively) and less than 5% of the fish in Strain C were maturing. Thus, it was possible to classify fish as mature (grilse) or immature (salmon) and, among the grilse, males and females could be distinguished visually. It was not possible to reliably sex the immature fish.

The mean November lengths for Strains A, B and C were 59.0, 54.8 and 51.1 cm, respectively. Although the grilse and salmon strains were grown in different years, with the attendant environmental differences that exist between years, the first-year growth rates of the grilse strains were clearly superior.

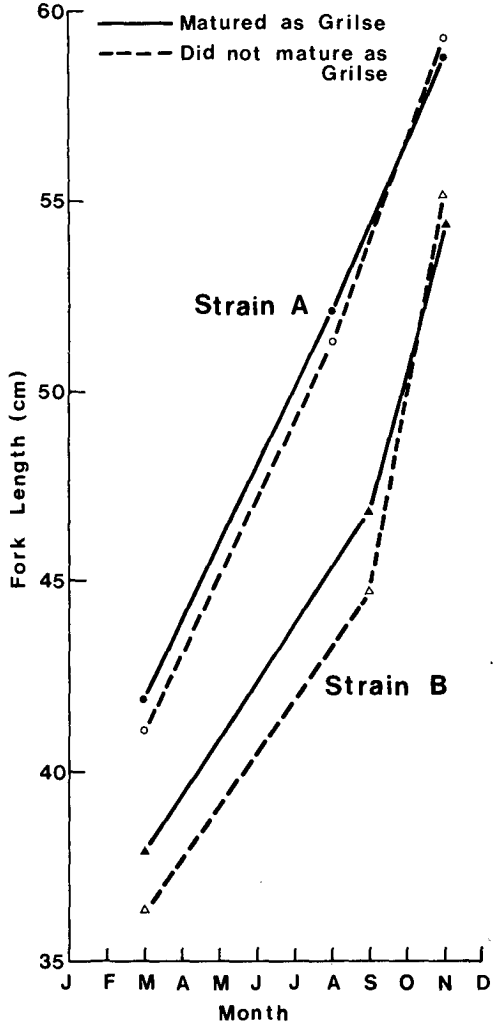


Figure 3. Mean fork lengths for maturing and non-maturing Atlantic salmon after 8, 13 and 16 months in sea cages.

The sampling results for Strains A and B are illustrated in Figure 3. The larger 2 + smolts of Strain A retained their size advantage throughout the study period. Also apparent for the first two samples in both strains is the relatively larger size of the fish which eventually matured as grilse. However, after August, when gonad development becomes important, the non-maturing fish caught and surpassed the grilse.

These results, coupled with the relatively high heritability estimates reported for growth rate and their shorter generation interval, suggest that grilse are more efficient than salmon up to the grilse stage and should, therefore, be good candidates for growth rate selection. It should be possible to develop grilse strains that are more productive than salmon strains for aquaculture. Perhaps one should ask the question, from an economic standpoint, is it more desirable to raise more large grilse relatively quickly, or fewer very large salmon relatively slowly?

Cooperation with cage sites

Fundy Aquaculture on Grand Manan cooperated in the rearing of Strains A and B, commencing with the placement of smolts in the Spring of 1984. Strain A was represented by 2 + smolts and was spawned in November of 1985 to establish the control and selected lines previously described. Strain B was represented by 1 + smolts. Grilse parents yielded the gametes for the high and low furunculosis matings in 1985. Repeat spawning of these fish and maiden spawning two-sea-winter salmon in 1986 accommodated further matings for the high and low furunculosis studies, the establishment of the Strain B control line and special matings of salmon-grilse combinations described later.

Strain C was placed at Fundy Aquaculture as 1 + smolts in 1985 and is proposed for the establishment of control and selected lines in 1987. A back-up for this population was provided through the placement of 1 + smolts placed at the cage site of E. Carpenter on Deer Island in 1986.

In 1986 Strain D 1 + smolts were placed with the new Salmonid Demonstration and Development Farm (SDDF) in Lime Kiln Bay. Similarly, 1 + smolts of Strain A control and selected lines will be placed at SDDF in 1987. Back-ups for Strain D were placed in 1986 and for Strain A will be placed in 1987 at the cage site of E. Carpenter, Deer Island.

Close cooperation with the cage industry has become an integral part of the SGRP.

Release and return experiments

G. W. Friars, SRC: R. L. Saunders, DFO, St. Andrews;
G. J. Farmer, DFO, Halifax and H. C. Madill, SRC.

Multiple-sea-winter fish are of interest to the angler because of their large size. This interest has encouraged study of sea ranching experiments with Strains C and D as well as Strains A and B.

Return rates in the SGRP reached a high of about 2.5 percent for some stocks, in the early years, where Big Salmon River genes were involved. However, in recent years the returns have declined to below one-tenth of one percent. Experiments have been initiated to study possible causes for the low returns.

Picture 6. A recapture facility is required in release and return experiments. (Courtesy ASF)

Split releases

An experiment carried out with the release of Strains C and D 1 + smolts, in 1985 and 1986 respectively, involved the transport of half the fish from each family to the Letete Passage in the outer Passamaquoddy Bay area about 10 miles from Chamcook Harbour and beyond herring weirs. This transport involved the towing of smolts in a semi-submersible barge in which the fish were exposed to the water through which they were being towed. The second half of

the smolts were released directly into Chamcook Harbour. Distinguishing marks on each fish allowed the identification of the group released at each site. Grilse from Strain C released in 1985 returned in 1986. Seven returning grilse, from each release site, were captured in the SRC weir. The data, though meager, do not suggest either an advantage or a disadvantage of towing smolts to an area beyond herring weirs.

Despite some limited evidence of SGRP marked fish straying into the nearby St. Croix and Magaguadavic Rivers, the low number of returnees (14 of Strain C) is of concern. However, these fish represent Strain C which is from a Saint John River gene pool. This stock has manifested a very low incidence of grilse in sea cages but somewhat higher frequencies in the Saint John River. Hence, the low return of grilse may not be out of line. Nevertheless, the low return of multiple-sea-winter salmon to the Chamcook location over the years is not encouraging with respect to Strain C returning two-sea-winter salmon in 1987. The replicate of the barge-towing experiment with Strain D should produce returning grilse in 1987 and two-sea-winter salmon in 1988.

Another experiment involving the split release of Carlin tagged 1 + Strain D smolts reared at the SRC included releases at the SRC (2300 smolts), Mactaquac Hatchery (2400 smolts) and St. Andrews Biological Station (2400 smolts) coupled with a release of 4000 Carlin-tagged 1 + smolts reared and released at Mactaquac. Mactaquac is located on the Saint John River just north of Fredericton, N.B. This experiment should shed light on whether the low return rates at the SRC are attributable to site of rearing or site of release.

A supplementary experiment involved Strain C 2 + smolts released at SRC (3250 with a right ventral clip) and at the St. Andrews Biological Station (3604 with a left ventral clip). This experiment should indicate whether the return problem is general for Passamaquoddy Bay or specific to the Chamcook Harbour at SRC.

High seas observations on SGRP fish

A letter was received from I. C. Russell, Ministry of Agriculture, Fisheries and Food, Fisheries Laboratory, Lowestoft, Suffolk, England, NR33 OHT. This letter was accompanied by two microtags recovered from the Greenland fishery in August, 1986. These tags were read and identified, one with the 1982 and one with the 1983 year class of the SGRP releases. These observations indicate that there is an involvement of SGRP fish in high seas fisheries.

Cormorant depredation of SGRP smolts

A summer student, F. P. Kehoe, assessed the effect of cormorant depredation on SGRP returns in the Spring and Summer of 1986. An abstract of the report of the study follows:

Apparent increases in cormorant populations have coincided with decreases in return rates of Atlantic salmon smolts from the Salmon Genetics Research Program in Passamaquoddy Bay, New Brunswick. In 1986, cormorants were collected to investigate the possibility of cormorant depredation

contributing to this decline. The proportion of smolts in the stomachs of a sample of 117 cormorants was approximately 0.10%. One Carlin and 16 micro tags were recovered in guano samples taken from four cormorant colonies. Fourteen of these tags were identified with eight different year classes of smolts released between 1976 and 1986. The estimated depredation rate from the 1986 release was 0.20%. It was concluded that cormorants are a relatively minor factor affecting return rates of salmon in the SGRP.

Grilse and multiple-sea-winter salmon crosses

R. R. Claytor, DFO Moncton; G. W. Friars and J. K. Bailey, SRC, St. Andrews

The prediction of whether smolts in a stream have a tendency to return as grilse or multiple-sea-winter salmon bears on angling interests. Evidence suggests that such predictions may be possible, using ovarian development in smolts as an indicator. Additionally, where incidences of grilse versus multiple-sea-winter salmon have a definite bearing on cage production, the effect of the sea age of parents at sexual maturity is important.

The availability of both repeat spawning and maiden spawning two-sea-winter salmon in Strain B in 1986 made it possible to make matings of the type depicted in Figure 4. Seven sets of the mating design were made at spawning time. However, the discard of eggs due to bacterial kidney disease being detected in the ovarian fluid or milt of the parents and poor survivability in certain small lots of eggs left approximately one half of the progeny groups for study beyond the fry stage.

The experiment entails the evaluation of oocyte development at the smolt stage. Where samples of the various mating types are available, the progeny will be evaluated for age at sexual maturity in sea cages.

This cooperative project makes use of the grilse and two-sea-winter salmon mix in Strain B, with a view to the study of problems allied to both anglers and culturists.

REARING PROGRAMS

Photoperiod after first feeding

K. A. Coombs, G. W. Friars, H. C. Madill and J. L. Delabbio[1].
SRC
1. Current address: Huntsman Marine Laboratory, St. Andrews N. B.

An aim of hatcheries is to have an early first feeding in order to accelerate growth. This allows a head-start for fish to be placed in outside tanks in early summer. A study to evaluate the effect on fry growth of different photoperiod and light intensity treatments was conducted at first feeding in 1985 and 1986. In 1986 the experiment was extended to examine if any post treatment effects were evident prior to smoltification.

Three photoperiods, 12 hours, 24 hours (continuous light) and simulated natural photoperiod (SNP), from April to June, and three intensities (10, 25 and 40 watt incandescent bulbs) were tested during a factorial design. In addition, gro-lights were tested in a SNP in 1985, and gro-lights and 15 and 60 watt fluor-

escent bulbs in a 24-hour photoperiod in 1986. Fish in the 1986 experiments were transferred from the hatchery to outdoor tanks where duplicates were combined, at the end of June 1986, to examine post-treatment effects under a natural photoperiod.

Table 4. Mean[1] weight (g) and forklength (F.L., cm) for the different photoperiods.

Photoperiod	1985			1986			
	4 weeks	8 weeks		4 weeks		8 weeks	
	WT.	WT.	F.L.	WT.	F.L.	WT.	F.L.
12 hours	.27	.93	4.61	.24	3.01	.68	4.03
24 hours	.32	1.07	4.82	.35	3.31	1.08	4.70
SNP	.31	.96	4.60	.27	3.11	.84	4.35

1. The Duncan's multiple range test of the means indicated that the 24-hour photoperiod was significantly ($P < .05$) different from the 2-hour and SNP. At 8 weeks in 1986, all 3 photoperiods were significantly different ($< .05$).

An analysis of variance was applied to the data for both years separately and with the two years combined. Photoperiod has a significant effect on growth of fry, the most growth occurring in the 24-hour photoperiod (Table 4). Intensity has no significant effect on growth. In a combined year model (3x3 analysis), growth in the 24-hour photoperiod was significantly better and the effect of light intensity was not significant.

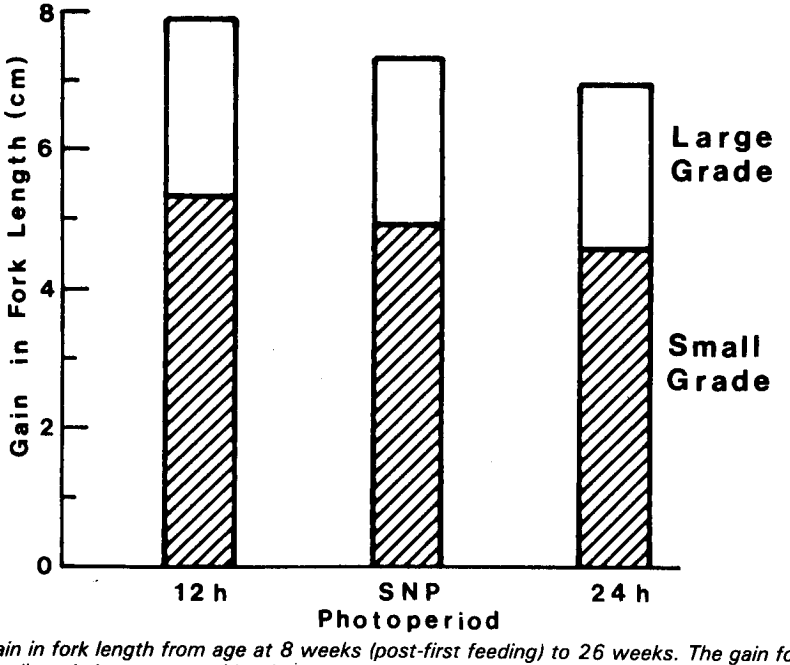


Figure 4. Gain in fork length from age at 8 weeks (post-first feeding) to 26 weeks. The gain for the small grade is represented by the cross hatch. The gain for the large grade is shown by the entire bar. SNP represents simulated natural photoperiod.

When examining the post-treatment effects (26 weeks post first-feeding), there were no significant differences in weight, forklength or the proportion of fish in the large grade. It appears that the smaller fish, in the SNP and 12-hour photoperiod treatments, caught up to the larger fish, and in fact, had the most growth by 26 week post-first-feeding. (Figure 4).

Despite an increase in size by photoperiod manipulation in the hatchery, the larger fry did not maintain this size advantage once placed outside. This is an important consideration for hatcheries trying to increase growth. It appears that growth enhancement, due to extended photoperiods in the hatchery together with additional feeding in this case, can be lost during later growth.

Extended fall photoperiod

A.R. Hanke, University of N.B., Saint John, N.B.; G. W. Friars, SRC:
R.L. Saunders, DFO, St. Andrews, N.B.

Several years of research by Dr. R. L. Saunders has revealed that increasing the photoperiod or day length from natural day length (NDL) to 16 hours (16 hr), during the period (September to December) markedly increased the length and weight of parr. The use of the extended photoperiod practices in the SGRP is being considered. However, there is a concern as to whether all families would react similarly to the extended day length. To answer this question, samples of two hundred fish from each of 36 families in the Strain A selected line were used in an experiment, where each family was involved in four replicates of each of the NDL and 16-hr. photoperiod treatments.

The growth data have been collected and will be analyzed by A. R. Hanke for his M.Sc. thesis. A salinity challenge on approximately 1100 of these fish will indicate whether the increased Fall growth relates to better salt water tolerance at the smolt stage. If the families have responded similarly in these trials, the 16-hr. day length may be incorporated into the Fall rearing routines with the SGRP.

Fibreglass versus concrete tanks

The growth of parr, reared in 25-ft. diameter outside tanks, was superior for fibreglass in contrast to concrete tanks (1985/86 SGRP Annual Report, Table 5). A well-balanced experiment, as described in the comparison of the control and selected lines with equal numbers of fry from each of 84 full sib families, was conducted in 1986/87. Growth and related traits observed on these fish, placed in the outside tanks in early July and measured between mid-January and mid-March, appears in Table 5.

The proportion of fish longer than 13 cm by January-March, 1986 was greater for parr reared in the fibreglass than the concrete tanks in the 1985 year class (Table 5), substantiating the same result in the two previous years. The differences in the mean fork lengths were not significantly different between the two types of tank material, where the advantage in growth for the fibreglass tanks was largely attributable to the proportion greater than 13 cm.

The differences in sex ratios (Table 5) indicated a predominance of males in the parr and females in the smolts, as in the case of control versus selected (Table 3). The 8 percent difference (48.0 versus 40.0 for fibreglass in contrast

Table 5. Growth and maturity traits of 1985 year class fish reared in fibreglass and concrete tanks between the fry and smolt stages (early July to the mid-January - mid-March period)

Trait	Rearing tank material	
	Fibreglass	Concrete
Percentage of smolts	68.5 *	63.1
Mean length of parr	11.1	11.1
Mean length of smolts	16.5	16.2
Percentage of male parr	68.4	69.8
Percentage of male smolts	48.0	40.0
Fin index[1] (%)	3.45	4.05

* Difference significant at $P < .05$.

1. Fin index ranged from 0 to 3 for no erosion to the worst erosion over five finds for a possible total of 15. The value in the table represents a percent of the possible total.

to concrete) is not significantly different, where the standard deviation of the binomial is 3.4 percent and approximately four times this difference would be required for the difference to be significant at $P < .05$

The reason for superior growth in the fibreglass tanks, in contrast to the concrete, is unclear. A suggestion that fin condition be recorded was made by Mr. John Ritter at the SGRP Steering Committee meeting in February. Each of four fins (right and left pectoral upper and lower lobes of the caudal and dorsal) were subjectively scored for degree of erosion on a scale of 0 to 3, making a total score that could range from 1 to 15.

The data (Table 5) are expressed on a percentage of a possible total of 15 per fish. The percentage erosion was higher for the concrete than for the fibreglass tanks (4.05 vs 3.45). Although this difference is not significant, it is in line with the better smoltification percentage in the fibreglass tanks.

The increased smoltification rate due to tank type appears to be additive to that for the select versus the control line. Where tank types are concrete (C) and fibreglass (F) and lines are control (R) and select (S), the means for percentage smoltification are as follows:

CR	59.4
CS	65.9
FR	64.9
FS	72.1

Hence, the environmental and genetic effects are cumulative in this case.

COOPERATIVE RESEARCH

DFO cooperation

Several areas of research described earlier in this report have involved cooperation, with DFO researchers, namely:

1. R. L. Saunders, St. Andrews — in the split release experiments and in the extended Fall photoperiod experiment.
2. G. J. Farmer, Halifax — in a split release experiment.
3. G. Olivier, Halifax — in the furunculosis resistance studies.
4. R. R. Claytor, Moncton — in the grilse x salmon cross study.

University of New Brunswick

The thesis research of A. Hanke on extended photoperiod involves J.M. Terhune as co-supervisor with G.W. Friars (cross appointment with UNB-Saint John). J.A. McKenzie and W.R. Knight, U.N.B., Fredericton and R.L. Saunders, DFO, St. Andrews, serve on the Supervisory Committee.

Undergraduate theses of Peter Huzinger and Robb Beaumont have involved SGRP staff in consultations on theses topic concerned with the monitoring of flow rates under the supervision of Mr. Mark Sanford and Dr. John Burgess.

Université de Moncton

Mr. Yves Doucet, Cadmi Microelectronique, Inc. is cooperating with SRC in connection with automated methodology for the measurement of fish.

Huntsman Marine Laboratory

B. D. Glebe in the synchronization of spawning and sex reversal studies.

Memorial University

G. L. Fletcher has used SGRP fish, reared at SRC, in research involving the injection of antifreeze genetic sequences into Atlantic salmon eggs.

University of Guelph

I. McMillan is cooperating with SGRP researchers in the fitting of exponential polynomials to bimodal parr data.

St. Francis Xavier University

D. M. Blouw is using fish from the extended photoperiod experiment to partition genetic and environmental effects on morphometric and meristic traits.

Additionally, many visitors and phone calls from interested institutions form part of day-to-day routines.

Steering Committee

Dr. R. H. Cook, Chairman, Dept. Fisheries and Oceans (DFO), St. Andrews, N.B.
Dr. J. S. Campbell, DFO, Moncton, N.B.
Dr. W. M. Carter, Atlantic Salmon Federation (ASF), St. Andrews, N.B.
Dr. A. T. Bielak, ASF, Montreal, Québec.
Mr. N. E. MacEachern, DFO, Halifax, N.S.
Dr. J.H.C. Pippy, DFO, St. Johns, Nfld.
Dr. G. R. South, Huntsman Marine Laboratory, St. Andrews, N.B.

This Committee met on February 19, 1987 following the meetings of the Scientific Advisory Committee and approved SGRP program plans and budget for 1987/88.

Ex officio Members: Dr. J.M. Anderson (ASF) and Dr. R.L. Saunders (DFO)

Scientific Advisory Committee:

Dr. J. H. C. Pippy (Chairman), DFO, St. John's, Nfld.
Dr. P. E. Ihssen, Ministry of Natural Resources, Maple, Ont.
Dr. G. F. Newkirk, Dalhousie University, Halifax, N.S.
Mr. D. G. Reddin, DFO, St. John's, Nfld.
Dr. R. L. Saunders, DFO, St. Andrews, N.B.

This Committee reviewed the SGRP on February 17 and 18 and made recommendations to the Steering Committee on February 19, 1987.

PERSONNEL INVOLVED WITH SGRP IN 1986/87

1. Fulltime SGRP staff

Dr. G. W. Friars, Chief Scientist
Mr. J. K. Bailey, Geneticist
Mr. H. C. Madill, Hatchery Manager
Mr. R. G. Carney, Assistant Hatchery Manager
Ms. K. A. Coombs, Research Technician
Mr. M. F. Dickie, Technician (to Sept. 14/86)
Mr. D. A. Johnson, Technician
Mr. T. E. Clark, Technician
Mr. R. G. H. Campbell, Technician (from Feb. 2/87)

2. Permanent ASF staff, part-time SGRP

Dr. J. M. Anderson, Vice President, Operations
Ms. S. A. Scott, Executive Assistant, Operations
Mr. J. W. Gibson, Technician (from Jan. 5/87)
3 Commissionaires
Ms. B. Johnston, Controller
Mr. D. Wylie, Buildings, Grounds and Vehicles Supervisor
Mrs. Irene Wylie, Janitor

3. Graduate student

Mr. A. Hanke, UNB-SJ, graduate student under G.W. Friars' co-supervision.

4. Temporary ASF - part-time SGRP

Norman Talbot Mais Intern (for the months of July and August):
Miss Alison Scarratt

Salmon Enhancement Technician Course, St. Andrews
Mrs. L. L. Sochasky (Coordinator)
Mr. E. R. Copeland
Mr. J. W. Gibson
Ms. B. J. Neilson
Mr. R. J. Watson

Canada Manpower Salmon Enhancement Technician Trainees for Florenceville Project:

Mr. Gilles Poulin
Mr. Brian Thornton

Huntsman Marine Laboratory Aquaculture Technician Trainees:

Ms. Ella Hoyt
Ms. Phyllis Franklin
Mr. Bernie Haun
Mr. Tony Baird
Mr. Bob Cotton
Mr. Brock Rhywold
Mr. Todd Turner
Mr. Conrad Allaine

Huntsman Marine Laboratory Canada Manpower Aqua Worker Trainees:

Ms. Kelly Brooks
Ms. Dawn Holt
Ms. Alice Holt
Mr. Bronson Saunders

6. Associated

Dr. B. D. Glebe, Research Associate
Dr. R. L. Saunders, Research Associate

INFORMATION RELEASE

SGRP staff have been involved in several areas of information exchange as follows during the 1986/87 year, as follows:

Type of Release	Number
Scientific papers	6
Papers at scientific meetings	5
Technical reports	7
Newsletter releases	3
Newspaper releases	10
Radio tapes	2
Seminars and workshops	65

SALMON GENETICS RESEARCH PROGRAM REPORT SERIES

Reports in this Series are issued periodically and reflect the activities of the Salmon Genetics Program. The Series consists of previously unpublished scientific material, reprints of primary scientific publications and administrative reports. These reports may be cited in other publications, but care should be taken to indicate the manuscript status of those other than reprints of published material. Some of the reports in manuscript form may later appear as primary scientific publications. Reference to previously published material in the Series should reflect its original publication status. Enquiries concerning reports in the Series should be addressed to The Salmon Genetics Research Program, Atlantic Salmon Federation, P.O. Box 429, St. Andrews, N.B. E0G 2X0.

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