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Report of the Working Group on Atlantic Salmon (Salmo salar) Broodstock Development and Conservation for the Southern New Brunswick Aquaculture Industry

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May 1989

Canadian Technical Report of Fisheries and Aquatic Sciences No. 1678

Fisheries and Oceans   Pêches et Océans

Canada

Canadian Technical Report of Fisheries and Aquatic Sciences

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June
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Cat. No. Fs 97-6/1678E ISSN0706-6457

Correct citation for this publication:

Ritter, J.A. (ED) 1989. Report of the working group on Atlantic salmon (Salmo salar) broodstock development and conservation for the southern New Brunswick aquaculture industry. Can. Tech. Rep. Fish Aquat. Sci. 1678: 24 p.

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Abstract

Ritter, J.A. (ED) 1989. Report of the working group on Atlantic salmon (Salmo Salar) broodstock development and conservation for the southern New Brunswick aquaculture industry. Can. Tech. Rep. Fish Aquat. Sci. 1678: 24 p.

This report addresses Atlantic salmon (Salmo salar) broodstock requirements of the southern New Brunswick aquaculture industry. It is the product of an industry-government Working Group struck by the Southern New Brunswick Aquaculture Development Committee. It reviews the current situation in the context of existing science and technology and outlines a recommended strategy for broodstock development and conservation.

The strategy involves a minimum annual production of 4,000 brood fish distributed among at least eight marine farms. Continued emphasis would be placed on preventing dissemination of diseases, particularly bacterial kidney disease, and to the extent feasible, the elimination of all diseases from the industry. All potential brood fish would be fed a specialized broodstock diet beginning early spring in the year of maturation. Food would be withheld at least two weeks, or perhaps up to four months prior to spawning, pending which strategy is shown by future research to be better. Movement of brood fish into fresh water, weeks or months prior to ovulation, although potentially a better strategy than the current practice of spawning fish taken directly from the sea, is not recommended for broad-scale use at this time because its application could be costly and the present practice is generally yielding favourable results. Due to uncertainty as to the breadth, source and mix of genes in the industry, a new strain, comprised of genes from the Saint John River population, would be created in each of the years 1987 to 1990. These four strains would represent the primary lines upon which mass selection would be carried out to increase the incidence of one-year smolts and growth rate during the sea phase, and to reduce the rate of early maturation as grilse. Transfer of technology pertaining to broodstock development and conservation would require improved coordination of supporting activities of governments and other public institutions, and both enhanced communication within and organization of the industry. Implementation of the proposed strategy would be facilitated through the formation of an industry-government committee charged with this responsibility.

RÉSUMÉ

Ritter, J.A. (ED) 1989. Report of the working group on Atlantic salmon (Salmo salar) broodstock development and conservation for the southern New Brunswick aquaculture industry. Can. Tech. Rep. Fish Aquat. Sci. 1678: 24 p.

Le présent rapport porte sur les besoins de l'industrie aquicole du Nouveau-Brunswick en saumons de l'Atlantique reproducteurs. Établi par un groupe de travail de l'industrie et du gouvernement mis sur pied par le Comité de développement de l'aquiculture du sud-est du Nouveau-Brunswick, il présente la situation dans le contexte technique et scientifique actuel et fournit des recommandations en vue de l'adoption d'une stratégie de développement et de conservation des stocks reproducteurs.

La stratégie en question repose sur une production annuelle minimale de 4 000 poissons reproducteurs répartis entre aux moins huit élevages marins. Elle viserait continuellement à empêcher la dissémination des maladies, en particulier de la maladie rénale bactérienne, et dans toute la mesure du possible, à éliminer toutes les maladies de l'industrie. Les reproducteurs en puissance seraient soumis à un régime alimentaire spécial dès le début du printemps de l'année de maturation. On les priverait de nourriture avant le frai, pendant au moins deux semaines, voire même jusqu'à quatre mois, selon ce que les recherches auront démontré à cet égard. Le déplacement des reproducteurs vers l'eau douce des semaines ou des mois avant l'ovulation, quoiqu'il puisse être préférable à la méthode actuelle (prélèvement direct dans la mer des poissons destinés au frai), n'est pas recommandé à grande échelle pour le moment, étant donné, d'une part, qu'il pourrait être coûteux et que, d'autre part, la méthode utilisée présentement donne dans l'ensemble de bon résultats. Compt tenu de l'incertitude qui règne dans l'industrie quant à l'ampleur, à l'origine et à la répartition des gènes, on créerait chaque année, de 1987 à 1990, une nouvelle souche fondée sur les gènes de la population de saumons de fleuve Saint-Jean. Ces quatre souches seraient la source primaire de la sélection massive que l'on effectuerait dans le but d'accroître le nombre de saumonneaux de un an et le taux de croissance pendant la phase marine du cycle du saumon et, également, de diminuer le taux de maturation précoce aboutissant à la production de madeleineaux. Le transfert de technologie nécessaire au développement et à la conservation des stock reproducteurs nécessiterait une plus grande coordination des activités de soutien du gouvernement et d'autres organes publics ainsi qu'une meilleure communication au sein de l'industrie et une organisation plus efficace de cette dernière. La mise en oeuvre de la stratégie proposée serait facilitée si elle était confiée à un comité créé à cette fin par l'industrie et par le gouvernement.

Preface

This report is the product of an industry-government Working Group established by the Southern New Brunswick Aquaculture Development Committee. The Working Group was comprised of smolt producers, marine cage operators and technical experts from provincial (New Brunswick Department of Fisheries and Aquaculture) and federal (Department of Fisheries and Oceans) governments and nearby research establishments. The charge to the Working Group was to develop a strategy for Atlantic salmon (salmo salar) broodstock development and conservation for the southern New Brunswick industry. The Working Group met as a group on two occasions (i.e., July 12-13, 1987 and September 16, 1987) to review the current situation and related information, and to develop a recommended strategy that would serve the requirements of the industry. Subsequent discussions between the chairman and individual Working Group members also contributed to the finalization of the strategy and this report.

Terms of reference for the Working Group and a list of participants including their respective areas of specialty or position, are given in subsections 10.1 and 10.2. Variation in the comprehensiveness of the different sections in the report reflects the level of information available.

A French edition of this report is available.

1.0 INTRODUCTION

The commercial culture of Atlantic salmon (Salmo salar) in New Brunswick began in the spring of 1978 with the initiation of the first rearing trials in saltwater at Deer Island (Sutterlin et al. 1981). This initial trial was a combined initiative involving the New Brunswick Department of Fisheries (now Department of Fisheries and Aquaculture), Fisheries and Oceans Canada, and private interests (A. MacKay and N. Adams). Salmon culture in New Brunswick has since evolved, within the private sector, into a major new industry involving 32 cage-culture operations in 1987 and an expanding smolt production sector. In the spring 1987, about 800,000 salmon smolts were distributed to sea-cage operations in New Brunswick, all situated in the southwestern Bay of Fundy. It is projected that these smolts will yield about 3,000 tonnes of salmon for marketing in 1988 and 1989, a level greater than the current Canadian harvest of Atlantic salmon in the public fisheries (Anon. 1987a).

The success of the salmon culture industry in the southwestern Bay of Fundy is largely the result of favourable environmental conditions. The most important environmental component, strong water currents and consequent high exchange rates through fish cages, results from the extreme tidal amplitude (7-8 m) in this area. In most locations, provided nets are clean, these strong currents produce rapid exchange through the cages, sweeping away uneaten food and feces and maintaining oxygen at near air-saturation levels. Salmonid feeding and growth are strongly influenced by ambient oxygen; any decrease below air-saturation results in reduced feeding and growth (Brett and Groves 1979). Also, moderate surface temperatures, seldom exceeding 14°C during summer, in the area where the cages are located (McGuire 1977), are contributing to rapid growth of cage-reared salmon. As a result of these favourable conditions, cage operations in the Bay of Fundy are producing a market-size salmon ranging from 6 lb (2.7 kg) to more than 12 lb (5.4 kg) in 16-18 months from the time of their introduction to the cages as smolts (E.B. Henderson, Salmon Demonstration and Development Farm, St. George, N.B., unpub. data). On most Norwegian farms approximately 24 months of rearing in the sea is required to produce a salmon of this size (Sutterlin and Merrill 1978; B. Gjerde, Agricultural University of Norway, Oslo, Norway, pers. comm.).

Low winter temperatures slow growth and threaten cage operations as they approach the lower lethal limit of - 0.7°C (Saunders et al. 1975). Low lethal temperatures are prevalent in most Atlantic Canadian marine areas, including parts of the southwestern Bay of Fundy (Saunders 1986). Except in a few marginally suitable and infrequently utilized areas in the southwestern Bay of Fundy, the New Brunswick industry has not experienced losses due to low lethal temperatures during the ten years of its existence. In contrast, the local thermal regime appears to be having a favourable modifying influence on age at first maturity. Consistently, the various salmon strains tested in sea cages have produced proportionately fewer salmon that mature after one winter in the sea (i.e., grilse) than when released as smolts to range free in the sea (Sutterlin et al. 1981; Saunders et al. 1983) or is apparent for the donor wild populations (R.L. Saunders, Department of Fisheries and Oceans, St. Andrews, N.B., pers. comm.). This tendency is particularly pronounced in Saint John River strains. Smolts released into the Saint John River produce grilse and multi-sea-winter salmon in the ratio of about 1:1, whereas comparable groups of smolts placed in local sea cages produce few or no grilse (Saunders et al. 1983). Low winter temperature has been suggested as the environmental variable most likely responsible for this modification in age at maturity. It is unknown if low winter temperature acts directly on the process of sexual maturation or indirectly through feeding and metabolic processes.

The southern New Brunswick salmon aquaculture industry is rapidly expanding. Projections are that production of salmon from cage operations in the southwestern part of the Bay of Fundy will reach and perhaps exceed 7,000 tonnes by the early 1990s. A key to maintaining and improving upon the existing competitive advantage that this local industry presently enjoys, lies with the application of a sound strategy for broodstock development and conservation. In recognition of the importance of this element, the Southern New Brunswick Aquaculture Development Committee, made up of representatives from industry and both levels of government, struck an industry-government Working Group to address salmon broodstock requirements of the New Brunswick aquaculture industry. This report is the product of the deliberations of the Working Group.

2.0 PRODUCTION AND MARKETING SCHEDULES

By the fall of 1982, New Brunswick's annual commercial salmonid aquaculture production was approximately 75 tonnes. Since 1984, annual production has approximately doubled each year with 150 tonnes being marketed in 1984/85, 250 tonnes in 1985/86 and 500 tonnes in 1986/87. Anticipated production in this New Brunswick industry is 1,600 tonnes in 1987/88, 3,100 tonnes in 1988/89 and 6,300 tonnes in 1989/90 (K. Wilson, N.B. Department of Fisheries and Aquaculture, Fredericton, N.B., pers. comm.).

Prior to 1987 most of New Brunswick's cultured salmon production was sold to markets in New Brunswick, Nova Scotia, Quebec City, Montreal, Ottawa and Toronto, with only a small percentage going into the United States (Boston and New York).

Beginning with the 1987/88 marketing season, sales to the United States expanded greatly. It is expected that 60 to 70 percent of the 1987/88 production will be marketed in the United States, primarily in the main urban centres in the eastern and mid-western states (e.g., New York, Boston, Detroit, Chicago)(W. Balasiuk, Atlantic Silver Ltd., St. George, N.B., pers. comm.). Markets in the United States are expected to account for 80 percent or more of the industry's total sales in 1988/89 and beyond (W. Balasiuk, pers. comm.).

Up to now, the marketing season for New Brunswick's production has extended from early August to early May of the following year, with most salmon sold from late November to late April. Beginning in 1988, year-round marketing should characterize the New Brunswick industry as it attempts to meet the strong market demand for a reliable year-round supply of quality fish (W. Balasiuk, pers. comm.).

In general, the preferred market size for cultured Atlantic salmon has been 6-9 lb (2.7-4.1 kg), although the upper level has usually been requested (W. Balasiuk, pers. comm.). With industry growth and projected market expansion into new areas, market demands are expected to encompass a wider range in fish sizes.

Present demands, originating in the market place, require the producers to have access to strains of fast-growing Atlantic salmon which yield low incidence of grilse. These strains would permit growers to compete successfully with the fishery on wild stocks by providing a 5-7 lb (2.3-3.2 kg) fish for the market during late spring and early summer, and would also meet the current major market demand for a 6-9 lb (2.7-4.1 kg) or larger fish later in the year. Development of faster-growing strains of salmon would enable New Brunswick's salmon culturists to be more competitive in both domestic and foreign markets.

3.0 BROODSTOCK REQUIREMENTS

No estimates exist as to the numbers of eggs that are likely to be available to the industry in 1988 and beyond. Most of the growers are generally hesitant to commit themselves to maintaining a broodstock considering that the total egg requirements of the industry could be satisfied by a small number of producers and that there exists no overall strategy pertaining to broodstock in the industry. In accordance with the current marketing schedule, the decision to maintain broodstock should be made at least fourteen months prior to egg-take.

Broodstock requirements were estimated considering projected industry growth and reproduction efficiencies. The assumptions are:

(i) The industry will expand to 50 farms in the next couple of years and the average capacity of these farms will be 60,000 smolts per year. There were in 1987 32 cage operations in the southwestern part of the Bay of Fundy. At least five of these operations introduced more than 50,000 smolts into their cages in 1987 and others have business plans under which they would exceed the average capacity of 60,000 smolts assumed here. Given these assumptions it is estimated that smolt requirements for the southern New Brunswick cage operations will reach three million in the near future.

(ii) Survival rate between green egg and the smolt stage is assumed to be 33 percent. It is expected that the average survival rate will increase to 50 percent in the future with anticipated improvements in broodstock husbandry and expansion and stabilization of the smolt production segment of the industry.

(iii) An average fecundity of 8,000 eggs per female is assumed. Although anecdotal information suggests that average fecundity rates per female are generally 10,000 or greater, assumption of this lower rate compensates for that percentage of the broodstock that fails to mature after two winters in the sea or ripens too late to contribute to the annual egg-take.

(iv) An average male:female ratio of 45:55 generally agrees with anecdotal information. The greater prevalence of females among salmon chosen for broodstock is consistent with the sex ratio of one-year smolts of Saint John River origin (Ritter et al. 1986). Since sexing of the brood fish by external characteristics is not possible until the summer prior to maturation, it is unlikely that the sex ratio of the broodstock can be intentionally altered at the time that the brood fish are selected from the production-size lots (i.e., during January to March or before). It is therefore assumed that the sex ratio of the salmon chosen for broodstock will be consistent with that of the production-size lot from which they are selected.

Consistent with the aforementioned assumptions, it is estimated that nine million eggs are required to achieve the three million smolt production target. These eggs could be produced by 1,125 female, two-sea-winter salmon. Given the assumed sex ratio, 920 males would be intermingled with the females. Although this total broodstock could be distributed among four farms, it seems advisable that the total broodstock for the industry be expanded to 4,000 fish and that they be distributed among at least eight farms. The numbers of brood fish specified here represent the numbers after selection has taken place. Although this apparent excess of brood fish would buffer the industry against unexpected losses due to disease or acts of God, it would result in production of large numbers of eggs surplus to the requirements of the southern New Brunswick industry in most years. To ensure that this back-up is maintained over the long term, each broodstock holder would likely require assurance of markets for at least a portion of his egg production.

During the expansion years of the New Brunswick sea cage industry, egg requirements are likely to be as great as later because of lower efficiencies among new hatchery operations and increased demands for eggs from competitive industrial development outside the province. Hence, it would seem desirable to expand broodstock production immediately in the New Brunswick industry to about 4,000 fish. For security reasons, the sites on which brood fish are retained should be geographically isolated from each other.

Broodstock requirements for egg sales to operations outside the province or for smolt production destined for export (e.g., United States) are not included in estimates stated here. Should these requirements be large, the number of brood fish should be increased accordingly to ensure that these additional requirements did not encroach upon egg supplies to the local industry.

The Working Group reviewed the desirability of reserving marine sites, isolated from production operations, for the culture and maintenance of brood fish exclusively. It was noted that geographic isolation of brood fish from production fish would reduce the risk of disease introduction to brood fish. However, the isolation of all brood fish from production fish would neither eliminate the risk of disease introduction nor alter the chance of disaster attributed to physical environmental cause. Hence, the establishment of one or a few isolated broodstock farms would not eliminate the requirement for several back-up farms to ensure a supply of quality disease-free eggs for the New Brunswick industry. Also, the number of sites which are isolated from existing production operations and where broodstock farms might be established is limited, as most areas suitable for salmon culture are already occupied by a few to several cage culture operations. The Working Group concluded that egg supplies for the New Brunswick industry would be more assured by several small broodstocks, each geographically separated from the other and located within a production operation, than on one or a few isolated sites where operations were restricted to broodstock production only. In addition, industry members appeared reluctant to designate sites for broodstock only, considering the shortage of sites which are suitable for salmon culture and the more favourable economic return that could be realized by use of these sites for general production purposes.

4.0 BROODSTOCK HEALTH

4.1 DISEASES

4.1.1 Diseases of Concern in Broodstock Management

Diseases affecting broodstock management generally affect broodstock health and associated egg quality. Those attributed to bacterial or viral agents can also be transmitted vertically from parent to offspring in the fertilized egg and/or on the surface of the egg. The main diseases of concern are:

1. Furunculosis

This disease is caused by the bacterium *Aeromonas salmonicida*. It is capable of killing salmonids retained in either fresh or salt water. It has been transmitted to marine cage sites in southern New Brunswick via infected smolts. The disease is horizontally transferred in fresh water and on marine cage sites. Oral treatment of infected lots with oxolinic acid has proven to be an effective control method but eradication may only be possible through stock destruction. According to local experiences, carrier infected parr and smolts are capable of transmitting the disease (J. Cornick, Department of Fisheries and Oceans, Halifax, N.S., pers. comm.). Because of the wide-spread distribution of furunculosis in the province of New Brunswick, all smolts destined for the sea cages are carrier tested and those found positive are treated with oxolinic acid. Vaccination of all smolts with a combined vibrio and furunculosis vaccine, 45 days before transport to sea, is also a recommended and common practise. Although presumed not to be transmitted in the egg, furunculosis bacteria may be carried on the egg surface (J. Cornick, pers. comm.). Transmission via the egg may be prevented by iodine disinfection.

2. Vibriosis

This disease, caused by several species of the Vibrio bacterium (*Vibrio* spp.), is encountered almost exclusively in the marine environment. The disease affects all species and ages of salmonids. Infection is systemic, causing open lesions, and can result in heavy mortality if not controlled. The disease is normally controlled by oral administration of antibiotics, such as oxytetracycline. The use of a vaccine to control vibriosis has reduced the dependence on antibiotics. The disease is presumed not to be vertically transmitted in the egg (J. Cornick, pers. comm.).

3. Bacterial Kidney Disease (BKD)

The causative agent for BKD is the bacterium Renibacterium salmoninarum. The isolated incidents of this disease in the Bay of Fundy sea cages appear to have originated from infected smolts. Where introduced to a site, the disease has been observed to infect other lots of fish on the same site. BKD causes low levels of mortality in fish in the sea cages. Fish chronically infected are capable of surviving to maturity and have in previous years been used as broodstock. The disease does not appear to have a major effect on market quality since its overt symptoms (i.e., lesions) are usually confined to the visceral organs and kidney which are discarded. The disease appears to reduce the growth rate of salmon reared in the sea cages. BKD is the only local bacterial disease in fish that is known to be transmitted in the egg (J. Cornick, pers. comm.). The prescribed treatment with erythromycin phosphate is only partially effective in controlling the disease and eradication is impossible except by slaughter (J. Cornick, pers. comm.).

4. Enteric Redmouth (ERM)

This disease is caused by the bacterium Yersinia ruckerii. This disease has not been a problem in salmon while in fresh water, although the causative agent has been found locally in both wild and cultured fish in the absence of clinical symptoms (J. Cornick, unpub. data). Clinical outbreaks have occurred in cultured salmon on two occasions. Both of these outbreaks occurred in the same facility situated in Nova Scotia and were associated with stress stemming from poor husbandry conditions. Experiences within the Maritime provinces suggest that Atlantic salmon are more resistant than rainbow trout (S. gairdneri) to ERM bacteria (J.W. Cornick, pers. comm.). ERM bacteria are presumed not to be vertically transmitted in the egg (J. Cornick, pers. comm.).

5. Infectious Pancreatic Necrosis (IPN)

This viral fish disease affects only the fry stage and is easily managed through good husbandry. Older fish become refractory but may become carriers and transmit the disease to progeny. This virus is widely distributed in the absence of clinical symptoms in many species of finfish and shellfish. Brook trout (Salvelinus fontinalis) appear to be the most susceptible of the native salmonids. Positive diagnosis of IPN in Atlantic salmon is generally infrequent and carrying this virus has seldom caused mortality in those lots. There is no known treatment. Hitra disease, attributed to Vibrio salmonicida (Egidius 1987) and common to farmed salmon in Norway, is suspected to be linked to the presence of IPN (T.T. Poppe, National Veterinary Institute, Oslow, Norway, pers. comm.). The suggested mechanism for this association is one where IPN reduces the effectiveness of the immune response to Vibrio salmonicida bacteria and possibly other infectious agents. Hitra disease has not been encountered in Canada.

6. Salmon louse

This ectoparasite (Lepioptherius sp.) can be a problem in marine cage culture operations. The parasite erodes the skin in the head area, enhancing the susceptibility of the fish to infection, and causes mortality if unchecked (J. Cornick, pers. comm.). The problem is seasonal and peaks during autumn. Salmon lice have not posed a serious problem at most locations in the southwestern Bay of Fundy. Salmon lice are effectively controlled through therapeutic treatment with Nuvan, although currently there is concern regarding the toxicity of this chemical to shellfish (Egidius and Moster 1987). Use of this compound is likely to be curtailed because it is not expected to be granted license approval for use as a therapeutic for salmon lice.

4.1.2 Prevention and Control of Diseases in Broodstock

Good husbandry is an essential preventive measure for all bacterial and viral diseases affecting broodstock health and associated egg quality. Smolts introduced to saltwater are routinely vaccinated against furunculosis and vibriosis, a practise which appears to be effective. Disease outbreaks are generally controlled through therapeutic treatment.

Vertical transmission from parent to offspring of all diseases except BKD and IPN is prevented by disinfection of eggs (J. Cornick, pers. comm.). The treatment most commonly used is a ten minute immersion in a 100 ppm free iodine solution, buffered to a pH of 7.0. This treatment is used on green eggs immediately following water hardening, and on eyed eggs. Disinfection procedures will not control vertical transmission of BKD and IPN because both may be transmitted inside the egg.

Because of shortages of eggs in the past, eggs were collected from broodstocks known to be clinically infected with BKD. In these instances the fertilized eggs were separated by mating until the respective parents had been thoroughly screened for BKD. This screening procedure involved an examination of the carcasses for lesions and completion of fluorescent antibody tests on smears made from the kidneys. Egg lots originating from infected brood fish (male or female) were destroyed. In some instances when it was known months in advance of spawning that a broodstock was clinically infected with BKD, the brood fish were injected monthly with erythromycin phosphate, commencing three months before spawning. This procedure was implemented to reduce the infection load and prevent further spread of BKD within the broodstock. In spite of the apparent effectiveness of this procedure when applied under tightly controlled conditions, the procedure is not recommended for general application.

The strategy recommended to reduce the risk of transmission of BKD from broodstock to the progeny is to not strip eggs or collect milt from broodstock known to have a history of clinical BKD. The same severe control measure is not recommended at this time for IPN because of the widespread distribution of IPN in both freshwater culture facilities and wild salmonids, particularly brook trout populations, and the apparent absence of loss or evidence of other direct harmful effects. However, the diagnosis of IPN in broodstocks should not be ignored considering that its presence may reduce the resistance that the fish have to other diseases, a suggestion that has yet to be demonstrated. Until this possible association between IPN infection and other diseases is clarified, it would seem desirable to avoid collecting eggs or utilizing milt from brood fish carrying IPN, whenever possible.

Health status of broodstocks should be determined regularly by lethal sampling and monitoring for diseases of concern, preferably both during the previous winter and immediately prior to spawning. The first of these two monitors would provide the broodstock farmer and the industry as a whole with an early warning should a disease problem exist. Should a first monitor identify a disease problem on a particular farm, there would be sufficient time for the industry to react and arrange for selection and holding-over of salmon for broodstock on an alternate farm. The main concern is BKD, which can be vertically transmitted in the fertilized egg and is not controlled by surface disinfection of the eggs. Samples for the first monitor could be collected during marketing in January or February, thereby eliminating wastage. Similarly, scheduling of sampling for the final monitor in August or early-September would both provide the required check on the disease status of the broodstock and enable marketing of the carcasses of the fish sacrificed for the monitor. For both monitors, the sampling rate should be 10 percent of the population, up to a maximum of 60 fish. Farmers maintaining broodstocks would have to set aside extra brood fish, at the time that the fish were initially selected, to satisfy subsequent lethal sampling requirements for disease monitoring.

Wild brood fish contributing eggs or milt to the industry should also be monitored for diseases. Lethal samples for this monitor could be collected immediately after spawning, provided the fertilized eggs from the wild fish were maintained in isolation from regular hatchery production fish until test results, indicating clean health, were available.

Testing of brood fish for BKD is frequently done through an examination of the reproductive fluids using the fluorescent antibody technique. This test procedure may be used in place of the regular monitoring procedure conducted immediately before or after spawning should lethal sampling not be desirable. The regular monitoring procedure, involving lethal sampling, full examination of each fish, fluorescent antibody testing of kidney smears, and culture for kidney disease bacteria, is the preferred method of testing for BKD since it is presumed to be more thorough (J. Cornick, pers. comm.).

4.1.3 Interprovincial Egg Transfers

Interprovincial transfer of salmon eggs requires that the broodstock be certified under the Fish Health Protection Regulations (FHPR) (Department of Fisheries and Oceans 1984). The certification of cultured salmon broodstock held in marine cages is difficult to achieve under FHPR because of the requirements that the site had previously undergone four consecutive inspections showing none of the certifiable diseases present, and that there had been no introductions of the certifiable diseases or noncertified stocks since the first of the four inspections.

The problem of certifying eggs from broodstock retained in marine cages is currently being addressed by the National Registry of Fish Diseases. The Registry is examining a proposal made by Regional officials which recommends a series of changes to FHPR that would allow for the uncomplicated and orderly certification of eggs while maintaining the intent of FHPR. The proposed procedure involves: (i) the lethal sampling and testing immediately after stripping of all brood fish supplying eggs, for FHPR II pathogens (i.e., agents causing furunculosis, ERM, BKD, IPN, and certain other diseases not found locally); (ii) the temporary holding of the eggs, separated by matings, either in isolation in groundwater at the source facility or in quarantine at the recipient site, until test results are available; and (iii) the retention of only those eggs from matings found free of FHPR II pathogens. The safety of this proposed procedure is currently being tested through two experimental transfers of eggs, under Section 4 of the Fisheries Act, from New Brunswick cage-reared fish into quarantines in Prince Edward Island and Nova Scotia, where the resulting progeny will be monitored for diseases.

4.2 NUTRITION

Scientific understanding, and the local transfer of technology fundamental to Atlantic salmon broodstock nutrition, date back to 1978 when low hatchability was recorded for eggs collected from reconditioned Atlantic salmon kelts. This low hatchability was attributed to deficiencies in trace elements and vitamins (S. Lall, Department of Fisheries and

Oceans, Halifax, N.S., unpub. data). The development and use of a moist broodstock diet for kelts, containing mineral and vitamin supplements, resulted in improved hatchability of eggs collected from kelts reconditioned in subsequent trials.

4.2.1 Nutrient Requirements

Reproduction represents an important biological function that requires synthesis of sexual products from dietary nutrients. Successful reproduction is therefore dependent upon diets which meet the specific requirements of maturing fish. Information on the nutrient requirements for successful reproduction by fish is extremely limited. Nevertheless, a few short reviews have been published (Fontaine and Oliverau 1963; Hardy 1985; Luquet and Watanabe 1986). The following summarizes information on selected nutrient and dietary factors which play a role in Atlantic salmon broodstock nutrition.

1. Lipid

Dietary lipids serve as a source of energy and essential fatty acids (EFA), and also act as carriers for fat soluble vitamins. Fish lipid contains a high level of polyunsaturated fatty acids, mainly of the linolenic series (n-3 type). Mammalian lipids contain more saturated fats with unsaturated lipid of the linolenic series (n-6 type). Fish cannot synthesize fatty acids of either the n-3 or n-6 series and these types must be provided in the diet. The EFA requirements of broodstock Atlantic salmon have not been established. However, there is sufficient evidence from the fatty acid composition of various tissues to indicate that the n-3 type fatty acids are necessary in broodstock diets. A description of EFA requirements of fish may be found in Watanabe (1984).

The role of EFA has been implicated at each stage of ovogenesis. During the primary vitellogenic stages (when the gonado-somatic index is less than 0.5) ovarian tissue synthesizes lipids from acetate which are largely incorporated into the polar lipid fraction (Wiegand and Idler 1982). Although the synthesized lipids are incorporated into triglycerides at later stages of ovarian development, most lipids deposited in the yolk are derived from lipoproteins and vitellogenin. Recent works by Leger et al. (1981) and Leger (1987) indicate that lipoproteins are directed into yolk globules which are comprised of lipovitellin and phosvitin, whereas vitellogenin preferentially enters the oil globules which are made up of triglycerides. During ovogenesis the dietary lipids appear to be diverted from adipose tissue and deposited in the eggs. Adequate levels of EFA are essential for normal spawning and to ensure good hatchability of eggs (Leray et al. 1985).

Generally, herring, capelin and other marine fish oils supply adequate levels of EFA for brood fish. Vegetable oils, containing n-6 and n-9 fatty acids, interfere in EFA metabolism and cause subsequent embryonic mortality. High levels of dietary lipid (> 16%) should be avoided because they contribute to a greater deposition of visceral fat. High levels of dietary lipid, without an adequate source of antioxidants, can cause oxidation of the polyunsaturated fatty acid and adversely affect reproductive performance. Large deposits of adipose fat can interfere with the spawning process.

2. Dietary energy, protein and amino acids

Dietary lipid, carbohydrate and protein serve as sources of energy. It is generally accepted that fish rely to a large extent on lipid and protein rather than carbohydrate for energy. Whether protein calories are used for catabolic or anabolic purposes is dependent upon the quality of the protein and the availability of fat and carbohydrate calories which, if abundant, relinquish the protein for tissue production.

A low protein diet has no adverse effect on reproduction if sufficient energy is supplied by the lipid supplement. Watanabe et al. (1984) showed that a protein level as low as 28 percent in a diet containing 21 percent lipid was sufficient to produce quality eggs with good hatchability. Roley (1983) also reported that trout fed isocaloric diets containing 27 to 56 percent protein showed no significant differences in egg production, egg size or embryo survival. However, a balance between calories and protein level may be necessary to avoid the production of excessive visceral fat. The dietary energy level is an important factor in a broodstock diet because it influences the feed intake and consequently the supply of other nutrients.

Amino acid requirements of brood fish have not been established. However, both males and females reflect some characteristic changes in their amino acid metabolism during gonadal development. The concentration of free amino acid rises in the gonads during their development and falls in the liver. The proteins in the testes increase in alkaline amino acids (lysine and arginine) as they ripen. There is also a characteristic change in amino acid composition of eggs and sperm of repeat spawners (Timoshina et al. 1981).

3. Carbohydrates

Salmonids have a limited ability to utilize carbohydrate for energy purposes. The digestibility of starch derived from cereal grains is poor, but processing methods utilizing heat improve the availability of carbohydrates. Excessive amounts of carbohydrates in broodstock diets may be deleterious, producing abnormally high levels in the liver, thus increasing susceptibility to mineral toxicity and infections.

4. Vitamins

Vitamins are required for normal growth, maintenance and reproduction of fish. Early work on Atlantic salmon kelts showed that vitamin E and C deficiencies of fish are reflected in low concentrations of these vitamins in eggs (S. Lall, unpub. data). Generally, fish store fat soluble vitamins (A and K) in the lipid component of tissues. A dietary deficiency of water soluble vitamins causes faster depletion of the fat soluble vitamins. The ascorbic acid concentration of good quality eggs should be at least 60 μg/g of egg to achieve maximum hatchability (Sandnes et al. 1984). When preparing a moist feed it is necessary to provide a thiamine supplement because the raw fish ingredient contains the enzyme thiaminase which destroys thiamine.

Ascorbic acid is unstable in fish feed. Its stability is influenced by moisture content of the diet, processing methods, storage conditions and the presence of rancid oils and fats. Furthermore, there are leaching losses of ascorbic acid and other vitamins in the water. Therefore, it is common to add more than the recommended allowances of certain vitamins to compensate for such losses.

5. Minerals

Fish have the ability to absorb inorganic elements from both the water and food they consume, whether they are in fresh water or seawater. At least part of the salmonid requirements for calcium, cobalt, iron, magnesium, potassium, sodium, zinc and other minerals can be obtained directly from the water. Other minerals, such as chlorides, phosphates and sulfates, are more effectively obtained from the food. Often, interactions exist among certain elements, which affect mineral absorption from feed and water.

Limited work has been done on the effect of mineral nutrition on brood fish. Supplements of zinc and manganese trace elements have been shown to be indispensable for reproduction by both sexes (Lall and Hines 1985; S. Lall, unpub. data). A diet low in manganese causes high embryo mortalities and a poor hatching rate. Fish meal containing high levels of ash should be supplemented with adequate levels of zinc and manganese, since high ash content influences the bioavailability of these essential trace elements (Takeuchi et al. 1981; Lall and Hines 1985).

6. Pigments

It is well known that carotenoid pigments, mainly astaxanthin, are deposited in gonads, eggs and skin during maturation. Torrissen and Torrissen (1985) detected a decrease in the carotenoid content of the flesh and its mobilization into gonads approximately six months prior to spawning. The carotenoid content of skin increases in both sexes during maturation; the magnitude of the increase is higher in males than in females (Scnarevich and Sakhnenko 1971; Kritahara 1983).

Several physiological functions of carotenoids in salmonid reproduction have been suggested (Tacon 1981) but not demonstrated. They include biological roles (hormones, vitamins, growth promoters), respiratory function, increased tolerance of eggs to adverse environmental conditions (e.g. elevated water temperature, harmful lighting conditions), enhanced chemotaxis of spermatozoa and increased egg fecundity.

Addition of some form of the carotenoid pigments to the broodstock diet is recommended. No distinction as to superiority exists relative to the use of natural astaxanthin over the commercially produced cantaxanthin.

4.2.2 Diet Formulation and Feed Preparation

The moist diet originally formulated for reconditioning kelts has been modified to meet the requirements of maiden spawners reared in sea cages. Both moist and dry forms of the broodstock diet are available and used in the New Brunswick cage culture industry. Relative to grower diets, the broodstock diets contain higher levels of the trace elements (zinc and manganese), higher concentrations of both water and fat soluble vitamins and lower levels of dietary protein and lipid. Comparisons of the formulations of broodstock and grower diets for both dry and moist feeds are given in Appendix 10.3.

Broodstock diets should be manufactured from quality fish meal and fish oil. Manufacturers should guarantee the quality of ingredients and clients should regularly monitor the final product to ensure use of top quality feeds. Moist feed should be produced daily for immediate use. Dry feed should not be stored longer than 45 days. Both feed types should be free of mold and contaminants.

Following spawning, kelts should be fed a "reconditioner" feed, formulated with higher energy content than a regular broodstock diet.

4.2.3 Feeding Practices and Rates

Evidence indicates that both nutritional quality of the diet and feeding regime are important factors for complete gonadal maturation and high egg viability. Several studies have shown that long term starvation (eight or more months) is detrimental to the reproductive success of female trout (Bagenal 1969; Scott 1962; Billard and DeFremont 1980). Short term starvation (40 days) has no significant effect on egg hatchability and proximate composition of eggs (Ridelman et al. 1984). Recently, Springate and Bromage (1985) have demonstrated that feeding half ration to rainbow trout broodstock reduces fecundity, delays spawning time and reduces egg diameter and mean dry weight. Similar results have not been demonstrated for maturing anadromous Atlantic salmon which in nature generally cease feeding by mid-summer and frequently earlier.

To ensure that broodstock obtain the nutritional requirements essential for the production of viable eggs, potential brood fish should be fed a broodstock diet from early spring onwards in the year of maturation and before gonadal development is far advanced. Within the industry, success has been achieved by stopping feeding of brood fish in July or early August, i.e., 3-4 months in advance of spawning. Experience with other salmonids suggests that feeding should be gradually phased-out two to four weeks prior to spawning, which is early enough to prevent fecal contamination of the reproductive fluids. Which of these alternative feeding practices is better remains to be demonstrated.

Guidelines for feeding rate do not exist and should be developed taking the following factors into consideration: (i) feed intake is affected by water temperature; (ii) appetite decreases as the fish ripens; (iii) fish have daily requirements for individual nutrients which are related to water temperature, body weight and stage of maturity; and (iv) excessive feeding leads to a greater deposition of undesirable visceral fat which may interfere with the spawning process.

4.3 HUSBANDRY

Prior to their selection, brood fish are reared using the same husbandry practices as market fish. Special husbandry practices pertaining to broodstock care and management are generally applied to ensure the quality and integrity of the genetic material and to protect the potential brood fish against disease which would threaten their existence or render their reproductive products unsuitable for use. Most of these special husbandry practices pertain to care of the salmon after selection has taken place and during the final 8 to 10 months prior to spawning. This section deals only with the husbandry practices applied to brood fish in the 8 to 10 months leading up to and during spawning. Considerations and practices pertaining to disease, nutrition and genetics are reviewed elsewhere in the report.

The main concerns pertaining to broodstock husbandry practices relate to poor reproduction success experienced throughout the industry and most notable prior to 1986. Most of the eggs collected were from brood fish maintained in the sea until spawning. Egg viability was highly variable, leaving industry members to expect mortalities to the alevin stage to account potentially for between 20 and 80 percent of the eggs collected (C. Frantsi, Connors Bros. Ltd., Black's Harbour, N.B., pers. comm.; S. Roach, Sea Farm Canada Inc., St. George, N.B., pers. comm.). Private hatcheries currently program to procure three eggs for each smolt they plan to produce (C. Frantsi, pers. comm.; S. Roach, pers. comm.). Federal government hatcheries generally seek two eggs from wild stock sources for each smolt they plan to produce (J. Ritter, pers. comm.).

Private hatchery operators reported improved and generally acceptable viability rates for many egg lots collected in 1986 from cage-reared broodstocks, including those from brood fish maintained in the sea up to spawning (C. Frantsi, pers. comm; S. Roach, pers. comm.). The reasons for this apparent improvement in egg quality are not known but are presumed to be the result of several changes in nutritional practices generally implemented throughout the industry in 1986. The main changes made are the use of a broodstock diet from early spring onwards and the withdrawal of feed from brood fish in August or before. Other changes in husbandry, which included the transfer of some lots of brood fish into fresh water, either several weeks before or immediately prior to spawning, and the experimental use of a gonadotropin (i.e., luteinizing hormone releasing hormone - LH-RH of the mammalian gonadotropin) to advance and synchronize spawning, may also have contributed to the overall improvement in egg viability recorded in 1986 (C. Frantsi, pers. comm., S. Roach, pers. comm.).

The Working Group examined different regimes for broodstock production relative to their retention in the sea and/or fresh water. In the industry there are three alternative regimes in practice. They are: (i) the production and maintenance of brood fish in the sea from the smolt stage through until spawning (the most commonly used practice); (ii) the same as i except that potential brood fish are transferred to fresh water before spawning and retained there until after they have been spawned; and (iii) the production of brood fish in fresh water throughout (one existing operation). The second alternative, whereby brood fish are produced in the sea and then moved to fresh water for the final weeks prior to spawning, is more similar than either of the other regimes to the common tendency in nature where wild anadromous Atlantic salmon generally enter fresh water weeks (late-run salmon) or months (early-run) prior to spawning.

The Working Group, in considering the regime under which the broodstock is cultured from egg to spawning in fresh water, noted that this regime did not allow for evaluation of performance and effective selection for industrial traits of salmon in their marine phase. A freshwater broodstock operation should however, provide better opportunity for control against losses due to disease or other causes and also lend itself more readily to fish health certification than a marine production facility which would ordinarily produce large numbers of fish for the market and accordingly receive smolts from uncertified hatcheries. In the event that procedures for certification under FHPR are altered to enable the certification of eggs from marine cage-reared brood fish through a single inspection of the facility and/or contributing broodstock, the freshwater broodstock facility would cease to offer the advantage of being more readily certifiable.

The preferred husbandry strategy for broodstock, which would allow for performance testing and progeny selection, and provide quality eggs and early timing of ovulation, would involve the use of marine facilities for rearing and freshwater facilities for holding of fish prior to spawning. This is the regime under which brood fish are generally maintained in the Norwegian industry (Sutterlin and Merrill 1978; T.T. Poppe, pers. comm.), and which, on the basis of limited local information (C. Frantsi, pers. comm.; J. Ritter pers. comm.), appears to be yielding equal or better egg quality and earlier and more synchronized ovulation than maintenance of the brood fish in the sea through to spawning.

Experimental implantations of an LH-RH analogue have shown that through proper usage this technique can effectively advance and synchronize the date of ovulation among salmon retained in the sea (B. Glebe, Huntsman Marine Science Centre St. Andrews, N.B., pers. comm.). Gonadotropins prepared from pituitary extracts have been shown to induce gonadal maturation and ovulation in various fish species (Donaldson and Hunter 1985). Eggs collected locally following treatment using the LH-RH analogue usually had high rates of fertilization (i.e., greater than 75 percent), and were generally of equal or better quality than eggs spawned from non-implanted fish maintained in the sea up to spawning (B. Davies, Huntsman Marine Science Centre, St. Andrews, N.B., pers. comm.; S. Roach, pers. comm.). This apparent beneficial effect is presumed to be attributed to reduced handling of the implanted fish rather than the direct effects of the hormone (B. Davies, pers. comm.). Many of the untreated brood fish maintained in the sea would have been subjected to increased osmotic stress as a result of individuals being handled more frequently during the protracted period over which they were spawned (Allee 1981; Waknitz 1981). Higher blood and reproductive fluid osmolarities are the product of increased stress and both have been correlated with reduced egg fertility (Wertheimer 1984; Stoss and Fagerlund 1982). High reproductive fluid osmolarities have been shown to adversely affect sperm motility (Baynes et al. 1981; Billard 1983).

Gonadotropin hormones, such as LH-RH, are proving to be effective in research and development work requiring spawning time to be advanced and/or synchronized (G. W. Friars, Atlantic Salmon Federation, St. Andrews, N.B., pers. comm.; B. Glebe; pers. comm.). However, caution should be exercised relative to extending their use to commercial operations considering public concerns. Use of gonadotropins should be limited to research and development activities until public concerns and/or conceptions are addressed, and regulatory conditions for safe use are defined.

The reason for the protracted timing of ovulation by brood fish maintained in the sea through to spawning is unclear. Although high salinity may contribute to this condition, warmer sea temperatures in fall, a consequence of later cooling down than is common to local surface freshwater systems, is suspected to be the main factor (B. Davies, pers. comm.; R.L. Saunders, Department of Fisheries and Oceans, St. Andrews, N.B., pers. comm.).

The optimal time for transferring brood fish to fresh water is unknown. Presumably, brood fish should not be transferred before the maturity status can be discerned. According to Sutterlin and Merrill (1978), ripening female salmon in the Norwegian industry are distinguishable by the protuding anal papilla, a condition usually apparent by August. Local experience indicates that synchronized spawning in late October and early November can be achieved by transferring brood fish from salt to fresh water during September, or possibly later (B. Davies, pers. comm., J. Ritter, pers. comm.). Should transfers be made earlier, and brood fish maintained in constant low-temperature groundwater, egg size and quality are likely to be affected. Experience with wild salmon, retained in broodstock holding facilities at federal hatcheries, supports this suspicion. Specifically, early returning wild salmon, retained from spring or early-summer collections in holding facilities supplied with constant low-temperature well water, yielded smaller and poorer quality eggs than brood fish either retained in variable-temperature surface waters or collected later in the season (G. Farmer, Department of Fisheries and Oceans, Halifax, N.S., unpub. data).

Because of the potential risks of disease transfer, the freshwater facilities to which brood fish from the sea cages would be moved should be isolated from and independent of smolt production facilities. These specialized facilities could also function as isolation or quarantine units for eggs collected from brood fish brought on site.

Should it be necessary to spawn brood fish directly from the marine cages, it would likely be more convenient and possibly advantageous, considering the difficulties of working on the cage sites, to transfer male and female gametes separately to the recipient freshwater hatchery where fertilization and water hardening of the eggs could be carried out.

Contamination of the reproductive fluids with seawater is known to reduce sperm motility and thereby have a detrimental effect on egg fertilization (Schlenk and Kahmann 1938; Baynes et al. 1981). As well, recently fertilized salmonid eggs are sensitive to rough handling during the normal allowable transport time (i.e., the first 48 hours after water hardening) (D.F. Alderdice, Department of Fisheries and Oceans, Pacific Biological Station, Nanaimo, British Columbia, pers. comm.). Experience with Pacific salmon has indicated that unfertilized eggs and sperm can be stored several hours (i.e., at least eight hours) at cool temperatures (i.e., 0°C to 6°C) without adversely affecting fertilization success (Piper et. al. 1982). Presumably, good fertilization success could be achieved with Atlantic salmon eggs if the gametes were maintained at a cool temperature and fertilization and water hardening carried out within twelve hours of stripping.

5.0 GENETIC CONSIDERATIONS

5.1 INVENTORY OF EXISTING STOCKS

The documentation of strains previously or currently used within the industry was viewed as an initial step towards development of a breeding program. The following, although incomplete, served to identify the general status of strains in the industry.

1. Department of Fisheries and Oceans (DFO) Strains

DFO strains are the product of seed stock provided by DFO as eggs, fry, parr and smolts to support the development of the aquaculture industry. The various lots of seed stock provided by DFO generally originated from multi-sea-winter salmon either returning to the Mactaquac facilities on the Saint John River or produced on two different farms in the Bay of Fundy. A cursory examination of the background of these strains indicates that although they would have been largely (if not entirely) comprised of Saint John River genes, the breadth of their gene pools may have been severely limited as a result of the following circumstances.

i) Some of the subpopulations, produced upriver of Mactaquac Dam, may have been lost with the installation of the three hydro-electric dams at Mactaquac, Beechwood and on the Tobique River. The breadth of the gene pool for the natural spawning population returning to Mactaquac would likely have been greatly reduced in 1967 and 1968 when numbers of spawners were only about 1000 fish (Penney 1976).

ii) The general spawning procedure was to mate collectively three females with two males. Use of this procedure would have reduced the number of parents effectively contributing to the matings.

iii) The sequential movement of small production lots through the Mactaquac Hatchery and the provision of cage lots of 2,500 smolts from single rearing ponds may have resulted in many cage lots and even the total yearly allocation to an individual farm having originated from a small number of parents.

iv) Some strains transferred to the industry originated from a relatively small number of eggs (< 200,000) and because of high reproductive efficiency (8-10,000 eggs per female) and the spawning procedure used (refer to ii), are the product of small numbers of parents (e.g., some of the two-year smolt classes provided by Saint John Hatchery).

v) In some years more than 50 percent of the seed stock provided to the industry originated from multi-sea-winter salmon returning to the Mactaquac trapping facilities late in the year (i.e., during September and October). These late-returning, older salmon generally represent less than a quarter of the total return of multi-sea-winter salmon to Mactaquac and, considering the apparent heritability of time of return (Ritter 1972; J. Ritter, unpub. data), are probably representative of considerably fewer subpopulations than the total returns of salmon to Mactaquac.

vi) Several lots of seed stock were the product of eggs supplied by the aquaculture industry from 1981 to 1984 inclusive. Eggs obtained in 1981 and 1984 would have originated from small numbers of parents. Moreover, the cultured brood fish contributing eggs in all four years are presumed to have been the product of seed stock previously provided by DFO and therefore potentially of a narrow genetic base because of circumstances i to v.

2. Connors Bros. Strains

Connors Bros. Ltd. has pooled samples of eyed eggs from matings made at Mactaquac in 1985, 1986 and 1987. The matings contributing to these three strains were generally between the pools of eggs from three females and milt from two males. Each of the strains would have originated from matings involving more than 200 parents. These transfers of germ plasm to the industry represent a wide spectrum of Saint John River stocks. For reference purposes these three strains are designated as Connors Bros. strains 1985, 1986 and 1987.

3. Salmon Genetics Research Program (SGRP) Strains

The primary objective of the SGRP is to conduct scientific studies in genetics and breeding of salmonids. Four strains of salmon are being developed under the SGRP. Two of the strains (A and B) are from grilse parents and were intended to demonstrate the effectiveness of selection on sea ranching traits such as return rate and sea-migration behaviour. The other two strains (C and D) will be developed using two-sea-winter salmon parents and through selection for cage culture traits such as growth and survival. Strains A and B have been synthesized from crosses of different river populations and progeny are now at post-smolt and parr stages, respectively, following single generations of random mating. Strains C and D are from parents returning to Mactaquac, Saint John River. Strain D is scheduled to be spawned as two-sea-winter salmon in 1988. Strain C would have been spawned as two-sea-winter salmon in 1987 had it not been destroyed because of the presence of BKD.

The disease problem with Strain C has forced the resampling of the gene pool of salmon returning to the Saint John River. With the cooperation of DFO, Strain C was reconstituted during the 1987 spawning season with eggs from the late-run, two-sea-winter salmon returns to Mactaquac. Samples of 2,000 eyed eggs from each of 99 females, involved in a hierarchial mating system with 22 males, were transferred to the SGRP in January 1988.

Strains A and B are estimated to contain about 55 percent Big Salmon River genes, as more fish from this source returned than from other river sources (Bailey and Saunders 1984). Samples of genes from the Saint John, Magaguadavic, Waweig and Dennis stream of the Fundy area, and Rocky Brook and the Sevogle River of the Miramichi system, are also present in these strains. A grilse production of about 50 percent for these strains, when reared in sea cages, makes them undesirable for current cage culture use. The incidence of grilse production in strains originating from Saint John River salmon, reared under comparable conditions, is considerably less. Performance data for strains A and B indicate that salmon destined to mature as grilse have superior growth during the first sea-year compared with that of their multi-sea-winter salmon contemporaries (Anon. 1986/1987). This characteristic of rapid growth may auger well for the use of genes from these two strains to produce a fast growing salmon for an early market in spring and summer. Also, a correlated positive response in juvenile growth rate to selection for grilse length (Anon 1986/1987) indicates the possibility of gains from selection for juvenile growth rate in both smolting rate after one year and growth rate during the first sea-year. Strains A and B may offer an alternative in the future to strains originating from the Saint John River stocks considering their diverse genetic base and possible potential for rapid growth rate.

Strains C (destroyed because of disease) and D were derived from single-pair-matings originating from both early- and late-run subpopulations. Comparison indicates superior growth during the first sea-year by the late-run progeny (G.W. Friars and J.K. Bailey, Salmon Genetics Research Program, Atlantic Salmon Federation, St. Andrews, N.B., unpub. data).

Salmon within the southern New Brunswick aquaculture industry are derived largely from Saint John River stocks. However, the integrity of most cage-lots of salmon retained for broodstock is questionable, considering that salmon originating from rivers other than the Saint John (e.g., those contributing to the formation of strains A and B) have on occasion been introduced to the industry. Moreover, the breadth of the genetic base of existing broodstocks is unknown, as are the types of directed and inadvertent selection to which they have been exposed. Additionally, high demands for eggs by the industry are rumoured to have resulted in inappropriate salmon being spawned (e.g., grilse or slow growing individuals).

5.2 CHOICE OF FOUNDATION STOCK

The Saint John River gene pools appear to be the preferred source of genetic material for stock development in the southern New Brunswick industry, at least in the short term. This preference is based on availability of eggs and performance to date in the local industry, where salmon originating from this source have yielded low grilse rates while producing market fish of desired weight in 18 months of growth in sea cages. The performance of salmon from this source appears to be superior to that realized by European competitors. The Working Group speculated that it should be feasible to produce a 6-9 lb (2.7 kg-4.1 kg) fish, the preferred market size, in 9-12 months of sea-cage rearing as a result of genetic gains and manipulation of husbandry practices. Such advances might, in future, warrant consideration of foundation stocks from sources other than the Saint John River, including those that produce a high percentage of grilse.

5.3 SELECTION GOALS

The goals of selection must be considered in light of consumer demand and production profits. Another section of this report deals with consumer requirements. The integrated profits of the industry may have conflicting components where, for instance, the production of two-year (S_2) as opposed to one-year (S_1) smolts may not be profitable for a hatchery operation at a specified price difference, but may be both profitable and desirable to cage operators whose market capabilities are more fully realized through the use of S_2 smolts or a combination S_2 and S_1 smolts. The size advantage provided to cage culture operations by the S_2 smolts may be negated however, by a higher incidence of grilse. Tag recapture data from releases of S_1 and S_2 smolts into the Saint John River indicate a greater proportion of grilse in the returns from the S_2 smolts, which were generally larger than the S_1 smolts (Ritter et al. 1986).

Improved growth rate ranks ahead of other traits when considering selection strategies. In the broad sense, growth rate may be interpreted as either weight at a given age or age at a given weight. Achievement of a given weight at a younger age is the goal that will increase production efficiency both from the standpoint of lower maintenance costs for accumulated growth and faster crop turn over in fixed facilities, provided that seasonal limitations can be circumvented. However, dramatic reduction in age at a given weight has been accomplished in the broiler chicken industry through selection for weight at a given age (G. Friars, pers. comm.).

Traits such as incidence of precocious parr, age at smoltification (S_1 versus S_2) and age at sexual maturation (grilse versus older maturing salmon) are highly allied to improved growth rate (Saunders et al. 1982; Naevdal 1983; Ritter et al. 1986) and might be considered component traits. There is some indication that a combination of S_1 and S_2 sources of stock may be required to satisfy market requirements on a year-round basis. Whether environmental manipulation with such factors as heated water is more economical in attaining this end, in contrast to having separate S_1 and S_2 gene pools, needs to be assessed.

The genetic basis for incidence of grilse versus multi-sea-winter spawners has been demonstrated (Gjerde 1984; Ritter et al. 1986). Selection for growth rates that will allow early marketing may, in the long term, cancel concerns about grilse, as mentioned in the discussion of strains A and B.

Traits such as reproductive rate have low priorities as selection goals because of the low economic impact on the industry, even with substantial genetic gains beyond the existing high levels. However, selection for traits such as disease resistance and carcass quality may warrant consideration. Family selection would be employed for these traits. In such cases, attention would need to be given to the likelihood of reducing the numbers of effective parents and accordingly special measures would be required to minimize inbreeding.

5.4 BREEDING AND PROPAGATION

The sampling of wild gene sources and the dissemination of genes throughout the industry may encompass several generations. To this end, the maintenance of a wide genetic base is essential, particularly in the primary breeding lines. Primary breeding lines are required in at least four consecutive years to provide for continuity of brood lines within the industry. A fifth breeding line would be required should continuation of the individual lines be through the production of S_2 rather than S_1 smolts. Both generation times assume that the brood fish mature as two-sea-winter salmon.

Because of uncertainty about the integrity and genetic diversity of the broodstocks currently in the industry, new primary breeding lines should be created. Potential sources of genes that could contribute to the development of new primary lines include the wild stocks of the Saint John River, salmon of known genetic background within the industry and strain D under the SGRP. Creation of new primary lines and their subsequent propagation might best be accomplished through a cooperative effort involving industry and both levels of government.

The use of mass selection without the consideration of family information can probably be effectively used to improve growth rate and production efficiency. However, selection within families can be effective in avoiding biases due to maternal effects on fry size and varying environmental conditions such as hatchery pond densities, use of different feeds or ration rates. Mass selection can probably be applied at different stages or times during the life cycle, such as in the freshwater growth phase or during the grow-out stage in the marine cages. Inbreeding could be kept to a minimum by passing genes between subpopulations, achievable by mating salmon of different sea ages (e.g., two-sea-winter with three-sea-winter salmon) or brood fish originating from S_1 and S_2 smolts. Inbreeding could also be reduced by transferring milt between broodstock farms. A selection of one out of two fish would be practical and should yield significant gains between generations with respect to incidence of S_1 smolts and growth rate in salt water.

5.5 REQUIREMENTS TO ACCESS WILD STOCKS

The need to access wild stocks largely rests with the requirement for development of the four or five primary breeding lines from sources of genes traceable to the Saint John River population. The first of these primary breeding lines was constituted in 1987 by sampling the multi-sea-winter salmon returning to the Mactaquac collection facilities. It may be necessary to resample this same source in subsequent years to establish other primary breeding lines, particularly those to be constituted in 1989 and 1990. At present, there appears to be adequate genetic material at the Salmon Demonstration and Development Farm for creation of the 1988 line.

The sampling of populations of other river systems may be required to investigate the potential attributes of their genes to the aquaculture industry. Similarly, it may be necessary in the long term to supplement genes within the industry by resampling of the Saint John River population. This may result from recognition of a desirable trait infrequently represented in the aquaculture lines but apparent in one or more subpopulations of the Saint John River, or because of requirements to restore greater breadth to the aquaculture gene pools after several generations of selection.

5.6 RISKS TO WILD STOCKS

The migration of genes into wild stocks through escapees from aquaculture operations was flagged by the Working Group as a potential consequence of the expanding New Brunswick aquaculture industry. The specific concern is that escapees from the sea cages would hybridize with the local wild stocks and thereby change the wild gene pools and subsequently reduce the fitness of the wild stocks. It is assumed that the wild stocks of rivers in the immediate area of the cage culture operations would be particularly vulnerable to introgression of aquaculture genes because of proximity and their small size (Saunders and Schom 1985). Although there are no documented cases where this form of introgression has reduced fitness in wild stocks, the specific concern expressed here is consistent with general concerns related to introductions and transfers of stocks frequently expounded by geneticists and managers of wild fish stocks (Altukhov 1981; Anon. 1982, 1984, 1986, 1987b; Stahl 1987).

The negative impacts of aquaculture stocks on the genetic integrity of the wild stocks would be eliminated if only sterile salmon were propagated in the sea cages. Although triploids or other forms of sterile fish are produced and used in experimental work, further development and refinement of methods are required before these techniques would be dependable under broad application. Propagation of genes from local wild populations should minimize the potential harm caused by escapees from aquaculture operations now and in the immediate future. However, with further expansion of the aquaculture industry and domestication of the aquaculture strains, the genetic risks to wild populations from aquaculture are potentially greater.

6.0 SUPPORT FROM PUBLIC INSTITUTIONS

Support for the salmonid aquaculture industry in southern New Brunswick comes mostly from public institutions which have traditionally been associated with the public fisheries. Although there was no established infrastructure to support the creation and early expansion of the industry, DFO and the New Brunswick Department of Fisheries and Aquaculture were responsible for its initiation, which they brought about by joining with private parties in 1978 to establish the first commercial-scale, salmon mariculture operation in New Brunswick. Since the beginning of the industry, governments have provided most of the science and technology, seed stock in the form of smolts, and financial assistance through loans and grants of various kinds. In the early years the industry was completely dependent upon smolts produced in DFO hatcheries. Although DFO continues to provide significant numbers of smolts to the industry (i.e., 150,000 sold to operators in both 1986 and 1987), private hatcheries are now the major suppliers of smolts. It is intended that DFO will cease supplying seed stock, other than for broodstock development, when the industry becomes self-sufficient.

New Brunswick Community College and Huntsman Marine Science Centre have conducted a successful 11-month Aquaculture Technician Training Program (ATTP) annually since 1977. The ATTP has graduated 10-15 aquaculture technicians each year since then. The SGRP, sponsored by DFO and the Atlantic Salmon Federation, began placing smolts on farms in 1980 to produce brood fish for its genetics studies. This activity has provided industry with additional smolts when they were exceptionally scarce and access to expertise in salmon genetics. In recent years, the SGRP has directed much of its effort toward development of technology in salmon breeding and strains of salmon with suitable traits for aquaculture.

In 1986 a Salmon Demonstration and Development Farm (SDDF) was established in the midst of the cage operations in the southwestern Bay of Fundy. The SDDF, largely funded under a Federal-Provincal Agreement on Economic and Regional Development (ERDA), was established to provide a testing ground for different types of facilities and equipment, and for evaluating alternate culture practices of interest to the developing industry. The farm also supports research activities pertaining to aquaculture, such as the SGRP and physiological studies. This new establishment is becoming a center for technology transfer and a base for extension services.

The Fish Health Service Unit of DFO provides fish disease diagnostic and counselling services for the industry and administers the Fish Health Protection Regulations and regional disease control policies and programs. In conjunction with these services the Salmonid Nutrition Unit within DFO is providing extension services in this area on the basis of ongoing research and development work in salmonid nutrition. The provincial Department of Fisheries and Aquaculture provides a local fish disease diagnostic service and a general extension service through which counselling is made available to farmers on fish health and general husbandry. It is expected that the newly formed Veterinary College in Prince Edward Island will institute an extension service for aquaculture operations in the Atlantic provinces as well as provide disease diagnostic services. In addition, the Huntsman Marine Science Centre is conducting research in reproductive physiology and working with the industry to resolve problems in this general area.

There are increasing numbers of workshops pertaining to nutrition, diseases and fish husbandry. In addition to the DFO-sponsored Annual Fish Health Workshop, there have been several smaller meetings dealing with problems and opportunities of the local industry. These have been sponsored mainly by the New Brunswick Department of Fisheries and Aquaculture.

The fish culture practices and the basic technology employed in the southern New Brunswick industry evolved from earlier research and development work conducted both locally and worldwide, largely by salmonid researchers. Despite the apparent well-being of the industry, the competitive advantage it maintains in the future will depend upon the success of ongoing and new research activities and associated technology development and transfer. Although some of the technology pertaining to broodstock development and conservation can be adopted from that applied in Norway and Scotland, the differences in geography, biological systems, environmental conditions, market demands and the maturity, size and diversity of the industry, demand application of technology developed locally. The needs of the New Brunswick industry are acute for increased research and support services if it is to maintain a competitive advantage in the market place.

7.0 TECHNOLOGY TRANSFER

Research is the precursor to technology development. Accordingly, rate of technological advancements in the southern New Brunswick aquaculture industry will depend upon availability of new science stemming from ongoing and future research initiatives in the aquaculture field.

No formal system exists for transferring technology to the salmonid aquaculture industry. Instead, technology has been transferred in an ad hoc manner and largely in response to recognized needs and opportunities. The first, and perhaps most significant of these transfers occurred with the initiation of the first commercial salmon culture operation in the southern Bay of Fundy. This first venture was undertaken as a combined initiative of both levels of government and two private individuals. Much of the technology incorporated in this initial trial was based on that used in Norway. Subsequently, other individuals in the private sector have copied and improved upon the original technology incorporated in the pilot operation.

Workshops and special meetings convened to address problems and issues have facilitated information exchange leading to technology transfer. The Atlantic Salmon Seed Stock Committee has been the most concerned of organized groups about broodstock availability and integrity. High performing breeding stock is available within the industry as a result of the transfer of genes from the Saint John River population through the sale by DFO of smolts of this origin as seed stock. Considerable effort has been made by individuals from the Huntsman Marine Science Centre to instruct industry members in stripping and fertilization techniques and in the use of gonadotropin hormones to synchronize spawning. The Nutrition Unit of DFO has formulated specialized diets for broodstock and worked with industry members to implement sound nutritional practices. The Fish Health Service Unit has provided training in fish disease diagnostics to industry members and graduates of the Aquaculture Technician Training Program. The Unit has worked with industry to screen individual brood fish for BKD and thereby has attempted to prevent the vertical transmission of this disease via the egg. Staff of the New Brunswick Department of Fisheries and Aquaculture have assisted in this effort. Most recently, the establishment of the Salmon Demonstration and Development Farm has provided a new opportunity for information exchange leading to technology transfer, including technology pertaining to broodstock development and conservation. It was noted that no local university provides a program that prepares graduates for aquaculture extension work.

The Working Group noted that there is a lack of written information on proven technology and research findings that might be applied within the industry. Interpretation and/or documentation of new developments in the relevent areas of science and technology were viewed as essential to keeping industry members informed of the most recent advances in the aquaculture field.

Despite the ad hoc manner in which technology has been transferred to the private sector, the requirements of the industry have been effectively satisfied up to now. However relative to broodstock development and conservation, the present approach to technology transfer is too fragmented to satisfy the industry's requirements in the future.

8.0 RECOMMENDED STRATEGY

The following details the recommended strategy for broodstock development and conservation for the southern New Brunswick aquaculture industry. The strategy is intended to serve as a present day guide for the industry as a whole. It is general in nature to allow both flexibility necessary for implementation and opportunity for change as the industry evolves. Its implementation would not preclude independent initiatives that could benefit an individual enterprise or the total industry.

8.1 BROODSTOCK REQUIREMENTS

The Working Group determined from a series of assumptions that the New Brunswick cage culture industry will in the immediate future require a minimum of 3.0 million smolts annually, which at current production rates will yield about 10,000 tonnes of salmon production. To ensure an adequate supply of quality eggs, the Working Group recommends that a broodstock of 400-600 fish be maintained on each of eight or more sites. Should large numbers of eggs be required for sale outside the southern New Brunswick industry or local smolt production targets in the private sector exceed 3.0 million, it would be necessary to increase proportionately the number of brood fish and possibly the number of sites on which they are held. The distribution of brood fish among several sites would reduce the impact of failure at one or more sites in a particular year. These sites should be geographically separated from each other to minimize the risk of catastrophe and independent of each other with respect to stock transfers.

It is imperative that the industry arrive at an understanding as to which growers will maintain broodstock. To maximize the opportunities for selection of the "preferred" fish from within production lots, individual growers maintaining broodstock should be committed to this role at least 12-14 months in advance of normal spawning time. To ensure continued commitment to the role of broodstock producer, industry will require agreement within, that all designated broodstock producers are guaranteed an equitable share of the local market for eggs. Should a designated producer not sell eggs in a particular year, because of a saturated local market, it is unlikely that he would continue to maintain a broodstock in subsequent years. Withdrawal of one or more of the designated broodstock producers from the program would reduce or eliminate the back-up supply of eggs required to ensure that the industry's egg demands are satisfied.

Under the proposed plan there would always be a surplus of eggs in the industry. Accordingly, this would allow smolt producers to be selective relative to brood fish health and genetic considerations when purchasing eggs.

8.2 DISEASES

The main fish disease concern pertaining to the broodstock program relates to the potential opportunities for proliferation and dissemination of pathogens via vertical transmission from parent to offspring. The Working Group recommends that all eggs be surface disinfected and none be collected from broodstocks having a history of clinical BKD.

The health status of all broodstocks should be routinely monitored twice before spawning, for all bacterial and viral diseases designated under FHPR. The first of these two monitors should be done in January or February, in the year prior to spawning. This initial monitor would provide the industry with an early warning should a disease problem exist. The final monitor could be done as early as late August or early September. Scheduling of the lethal sampling this early would enable the producer to market the carcasses of the fish sacrificed for the monitor. Sampling rates for both monitors should be 10 percent of the population, up to a maximum of 60 fish.

Wild broodstocks contributing eggs to the industry should be monitored at least once. Should monitoring before spawning be undesirable, lethal sampling could be done after spawning provided the fertilized eggs were maintained in isolation from regular hatchery production until test results were available.

The fish health status of all cultured and wild broodstocks contributing eggs to private aquaculture operations should be a matter of public record.

8.3 NUTRITION

Nutritional considerations specific to broodstock care are generally confined to the use of specialized diets and the withholding of food from prospective spawners. The strategy recommended for brood salmon is: i) they be fed a proven broodstock diet from early spring onwards in the year of maturation; and ii) they be taken-off all feed at least two weeks prior to spawning or perhaps considerably earlier. The withdrawal of feed from brood fish two to four weeks prior to spawning, will prevent contamination of the reproductive fluids and eggs with fecal matter. Best spawning success and egg quality might however, be achieved by stopping feeding as early as July or August, as is the current practice in the New Brunswick industry. The Working Group recommends investigation of alternate feeding practices for salmon broodstock to determine when feeding should be curtailed.

8.4 HUSBANDRY

In New Brunswick, most salmon eggs

from cultured broodstock are taken directly from spawners maintained in the sea. This practice of spawning fish taken directly from saltwater is yielding eggs of good but somewhat variable quality. An alternative practice, whereby brood fish are transferred from the marine cages to freshwater facilities, weeks or months prior to spawning, is viewed as potentially better. The advantages of transferring brood fish to fresh water a month or more in advance of spawning are likely to include better and greater consistency in egg viability, and earlier and more synchronized spawning.

The broad scale application of this potentially better practice is not recommended at this time because it would require development and operation of specialized facilities which could be costly and the present common practice is generally yielding favourable results. Because of disease risks, the Working Group cautions producers against transferring brood fish to a smolt rearing/production site unless the broodstock holding facility and its operation were isolated from the hatchery and its normal operation.

Ripening of brood fish retained on marine sites is generally not well synchronized. This lack of synchrony directly reduces the total egg-take from a particular broodstock and also necessitates greater handling which is presumed to stress the parents and lower egg viability. The Working Group acknowledges that spawning of brood fish retained in the sea could be advanced and synchronized through the use of gonadotropin hormones but recommends against their use in commercial operations until public concerns have been dispelled and regulatory conditions for safe use have been defined. Reduced handling of brood fish retained in the sea should improve the viability of the eggs, particularly those collected later in the spawning season.

Production and retention of salmon broodstock in fresh water is not recommended because the application of directed selection in fresh water would likely be less effective in improving stock performance in the sea and also, inadvertent selection occurring during rearing of the brood fish in fresh water may lead to reduced performance among progeny when later reared in the sea.

8.5 GENETICS

The general strategy recommended is that genes of Saint John River salmon be used to develop a minimum of four primary lines upon which selection could be carried out.

8.5.1 Choice of Foundation Stock

Adult salmon returning to the Saint John River are the recommended source of genes for the industry. This choice is largely based on past performance in Bay of Fundy sea cages of salmon derived from the population returning to Mactaquac on the Saint John River. Strains derived from this source have demonstrated excellent growth and low incidence of maturation as grilse.

8.5.2 Selection and Mating Practices

In consideration of consumer demand and industry profits, the Working Group recommends selection for improved growth rate in the marine environment, reduced incidence of grilse and increased rate of smolting at one year.

The use of mass selection is recommended over family selection as it would allow for wide scale application in the industry, while having the potential to be effective. The Working Group noted that it should be possible to keep inbreeding to a minimum through the passage of genes between both the four primary lines and the different sub-strains created with divergence from the base strains introduced to the industry. This passage of genes could be accomplished through: i) the transfer of milt between farms; ii) the cryopreservation and use of milt from different year classes; and iii) the crossing of salmon of different sea ages (e.g., two-sea-winter x three-sea-winter) or originating from S_1 and S_2 smolts. Family selection should be continued under the SGRP and improved strains introduced to the industry as they become available.

Intensity of selection will vary with the trait and the operation. For growth rate, a selection rate of one out of two fish would likely be both practical and effective. Selection to reduce the incidence of grilse would be accomplished by excluding grilse from all matings. Similarly, selection for increased rate of smolting at one year would be exercised by choosing all brood fish from production lots originating from S_1 smolts.

8.5.3 Strain Development

In view of the uncertainty of the breadth of the Saint John River gene pools contributing to the individual cage lots of salmon in the industry, with the exception of Strain D of the SGRP, the Working Group recommends the creation of a single new strain in each of the four years 1987-90. They are:

- Strain 1987 - made-up of genes from paired matings of two-sea-winter salmon returning to Mactaquac on the Saint John River. The matings for creating this strain were made in the fall of 1987.
- Strain 1988 - comprised of genes from strain D of the SGRP, retained at the Salmon Demonstration and Development Farm. Potential would exist to enhance the breadth of the gene pool by including in the spawning program, brood fish

originating from large grade, S_1 smolts from Mactaquac Hatchery.

- Strains 1989 and 1990 - also comprised of Saint John River genes, but the sources have yet to be defined. Possible sources include: two-sea-winter salmon returns to Mactaquac (i.e., like Strain 1987); Connors Bros. strains 1985 and 1986 which include representation from all matings made at Mactaquac Hatchery in 1985 and 1986; and brood fish originating from Mactaquac Hatchery S_1 and Saint John Hatchery S_2 smolts.

Strains A and B, created under the SGRP, may offer advantage to the industry should their growth during the first twelve months in the sea be superior to that of the four primary strains. Pending the growth advantage these two strains would afford the industry, they would offer potential to produce a market-size fish for spring and summer seasons. However, because of high incidence of grilse, strains A and B would not support a year-round marketing schedule unless their use was coupled with sterilization of all production fish, or they were produced in conjunction with strains which yield older maturing salmon.

8.5.4 Broodstock Propagation

The recommended strategy is to provide, in successive years, first filial generation (F_1) smolts of the four primary strains to eight or more broodstock propagators. The smolts should be one-year-old and available in minimum lot sizes of 2500. Lots of this size should allow for a one out of three selection and an annual production of 400-600 brood fish per broodstock farm. The same strategy could be applied to subsequent generations.

Production of the F_1 smolts of the first two of the four primary strains (i.e, 1987 and 1988) might best be carried out at the Salmon Research Centre under the SGRP and at hatcheries of DFO. Strains C (reconstituted) and D under the SGRP satisfy the basic requirements for aquaculture strains 1987 and 1988, respectively. The SGRP will be placing smolts from both these strains on at least two marine sites for evaluation and broodstock propagation. The operations on these marine sites could produce brood fish for the industry. Mactaquac and Saint John hatcheries of DFO could produce S_1 smolts originating from the 1987 egg take at Mactaquac Hatchery and distribute them to the other six or more broodstock farms. The other two primary strains (i.e., 1989 and 1990) should be produced at DFO hatcheries and one or two private hatcheries. The F_1 broodstocks should produce sufficient F_2 eggs to satisfy the industry's production requirements and allow for the continuation of the different breeding lines within the industry itself. At least two hatcheries and the same number of the broodstock farms should be assigned the role of ensuring continuation of the lines. The role of these operations would be that of primary breeders for the industry.

New or modified strains, arising from the ongoing SGRP or other development initiatives, could probably be introduced to the industry using the same general strategy described here for the four primary strains.

8.5.5 Maintenance of Strain Integrity

Breeding carried out by the primary breeders should be done according to guidelines or direction provided by geneticists. A central registry, in which records of ancestry of the different strains would be kept, should be established and updated annually. It seems appropriate that government, with the advice of local expertise in genetics and the assistance of industry, initiate the development of a central registry for maintaining the pedigrees of the different strains. It was noted that a clear record of breeding practices carried-out will be difficult to maintain and therefore dependent upon the full cooperation of all participants.

8.5.6 Reducing Risks to Wild Stocks

Broad scale use of sterilized animals in the industry would minimize the genetic risks to wild stock integrity, potentially caused by escapees from sea-cage operations. Accordingly, the Working Group recommends that emphasis be placed on technology development that could facilitate the creation and use of sterilized salmon throughout the production segment of the industry.

The Working Group recommends against the importation and propagation of eggs or other life stages containing genes originating from salmon populations outside northeastern North America.

8.6 TECHNOLOGY TRANSFER AND EXTENSION SERVICES

The Working Group concluded that while expertise is available, the present approaches to technology transfer and the provision of extension services pertaining to broodstock development and conservation, generally suffer from lack of coordination and clear definition of roles. Relative to the proposed strategy, the Working Group recommends that roles and responsibilities of the industry (smolt producers and cage operators), government (provincial and federal) support groups and other public institutions be clearly defined and that all supporting activities be coordinated. The strategy places new demands on the industry for improved communication and coordination within itself, and in particular, for a strong liaison between cage operators and smolt producers participating in the broodstock program.

8.7 RESEARCH REQUIREMENTS

The following list of recommended research activities reiterates areas of research previously identified in the report and identifies new research opportunities pertaining to broodstock development and conservation. The numbering system used is to facilitate referencing rather than to indicate priority.

8.7.1 Diseases

1. Confirm the effectiveness of egg surface disinfection procedures for bacterial agents causing furunculosis and ERM.

2. Investigate the means by which kidney disease bacteria are transmitted from parent to offspring with a view to developing a method for preventing vertical transmission of BKD.

3. Develop a sensitive, specific, nonlethal diagnostic procedure for screening broodstock for BKD.

4. Develop a rapid, specific, sensitive method to detect the BKD organism in samples of unfertilized eggs and milt.

5. Determine the significance of positive BKD fluorescent antibody tests relative to the potential for clinical disease outbreak and vertical transmission via the fertilized egg.

6. Develop an effective chemotherapy for BKD.

7. Develop an effective vaccine for BKD.

8. Develop an improved culture medium for kidney disease bacteria.

9. Investigate vertical transmission of IPN virus in Atlantic salmon with a view to developing a method for preventing IPN virus transmission from parent to offspring.

10. Investigate the hypothesized association between IPN infection and reduced disease resistance.

11. Develop an effective and environmentally safe treatment for salmon louse to replace Nuvan, the chemical agent which is presently used in the industry.

8.7.2 Nutrition

1. Examine eggs and seminal fluids from cultured and wild salmon brood fish to determine differences in chemical compositions (proximate, amino acids, & fatty acids, vitamins and trace elements).

2. Determine the quantitative nutrient requirements (protein, amino acid, lipid, minerals and vitamins) of salmon brood fish.

3. Determine the influence of dietary factors on brood fish health, including the role of nutrition in preventing infectious diseases (e.g., BKD).

4. Develop guidelines for feeding brood fish, including identification of the optimum time for curtailing feeding.

8.7.3 Husbandry

1. Compare the reproductive performance of brood fish retained in the sea with those transferred to fresh water weeks or months prior to spawning. These investigations should quantify the effects of the different husbandry practices on fertility of eggs and sperm, hatchability, fry size and timing and synchronization of spawning, and also, should identify the causes for the observed differences.

2. Develop optimum procedures for spawning brood fish moved to fresh water or retained in the sea.

3. Develop procedures for the separate transportation of eggs and sperm from Atlantic salmon (e.g., storage conditions during transportation, allowable storage time).

4. Develop procedures for the safe use of gonadotropin hormones to advance and synchronize spawning (e.g., hormone selection, dosage, time and method of application, residual effects and clearance time).

5. Develop a reliable method of sexing salmon that would enable early selection of the desired numbers of males and females to be retained for broodstock.

8.7.4 Genetics

1. Determine the effectiveness of selection and mating practices to increase growth rate in the marine environment, advance smolting age, reduce rate of early maturation as grilse and improve performance of other traits of economic consequence.

2. Investigate the potential damage to wild stocks of salmon from introgression of genes from aquaculture escapees derived from local and distant origin stocks,

respectively and from highly domesticated strains.

3. Develop sterilization procedures for salmon that are effective, economical and efficient, and which do not adversely affect performance.

4. Investigate subpopulations of both the Saint John River and other river systems for desirable traits that may be absent or infrequently represented in the aquaculture lines. Pending their discovery and potential significance to the industry, breeding programs could be developed to facilitate the incorporation of such traits into the primary lines.

5. Compare growth rates in the Bay of Fundy sea-cages for progeny of early and late-run components of the population of salmon returning to Mactaquac, Saint John River.

6. Investigate the potential of synthetic strains A and B of SGRP for cage culture use.

7. Investigate the potential for developing BKD resistant strains of salmon.

8. Develop cryopreservation procedures for salmon sperm and ova.

8.8 IMPLEMENTATION

Implementation of the proposed strategy is dependent upon its acceptance by members of the southern New Brunswick industry, both levels of government and other supporting institutions. Development of a clear understanding of the strategy by all interested parties might best be achieved by distribution of this report and a public discussion of it at a meeting attended by industry members and other interested parties. Should this general strategy be accepted, a comprehensive plan, detailing the various actions and individual responsibilities, would be required. The development and implementation of this plan would require input from hatchery operators, cage growers and both levels of government. The Working Group recommends that an industry-government committee be struck to carry out the detailed planning and oversee implementation.

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10.0 APPENDICES

10.1 TERMS OF REFERENCE

The Southern New Brunswick Aquaculture Development Committee (SNBADC) identified a problem of salmon broodstock supply. The Committee recommended that a Working Group be struck to review the salmon broodstock problem and provide direction to the Committee on both short-term issues and the long-term needs. On behalf of SNBADC, Dr. J.E. Stewart set out the terms of reference, an invited membership and a reporting date for the Working Group, in a

March 17, 1987 memorandum to J.A. Ritter, appointed Working Group chairman.

The terms of reference are:

1. Identify broodstock requirements to meet the needs of industry;

2. Identify present and future potentials of the industry to produce brood fish (technical aspects);

3. Identify fish health practices that contribute to the production of quality salmon eggs;

4. Identify genetic considerations and selection criteria (develop guidelines) for development of a salmon broodstock;

5. Identify and priorize areas of research required to ensure the development of a salmon broodstock for the industry;

6. Identify the roles of governments;

7. Identify future needs (if any) for access to wild stocks and non-indigenous stock (provide recommendations on appropriate policies);

8. Identify ways to improve technology transfer and information exchange on this matter;

9. Recommend regulating mechanism to protect broodstock integrity.

The following representatives from the various agencies were invited by SNBADC to serve on the Working Group.

Chairman (J. Ritter)
Liaison between government and industry (E. Henderson)
Fish Disease expert (J. Cornick)
Fish Physiologist (R. Saunders)
Seedstock Committee Chairman (D.J. Scarratt)
Provincial spokesperson (K. Wilson)
Geneticist (G. Friars, Salmon Genetics Research Program)
Cage operators (two representatives to be named by Atlantic Silver Ltd.)
Smolt growers (S. Roach and L. White)

The Working Group Chairman was asked to provide a final report by September 30, 1987. It was requested that the report follow the format of the Canadian Fisheries and Aquatic Science Technical Report Series.

10.2 LIST OF WORKING GROUP MEMBERS AND PARTICIPANTS

1. Members appointed by Southern New Brunswick Aquaculture Development Committee (SNBADC)

J. Ritter (Chairman)
- Fisheries and Oceans

W. Balasiuk (cage operator)
- Atlantic Silver Ltd.

R. Polland (cage operator)
- Atlantic Silver Ltd.

G. Gautreau for L. White (smolt producer)
- Atlantic Smolts Ltd.

S. Roach (smolt producer)
- Sea Farm Canada Inc.

K. Wilson (aquaculture biologist)
- N.B. Dept. of Fisheries & Aquaculture

G. Friars (geneticist)
- Atlantic Salmon Federation

E. Henderson (aquaculture biologist)
- Salmonid Demonstration & Development Farm

R. Saunders (physiologist)
- Fisheries and Oceans

D. Scarratt (Seedstock Committee Chairman)
- Fisheries and Oceans

J. Cornick (fish disease biologist)
- Fisheries and Oceans

2. Members appointed by Chairman (with the approval of SNBADC)

S. Lall (nutritionist)
- Fisheries and Oceans

C. Frantsi (smolt producer/cage operator)
- Connors Bros. Ltd.

3. Other participants

D. MacMinn (Deputy Minister)
- N.B. Dept. of Fisheries & Aquaculture

B. Groom (aquaculture biologist)
- N.B. Dept. of Fisheries and Aquaculture

B. Davies (physiologist)
- Huntsman Marine Science Centre

10.3 COMPARISON OF BROODSTOCK AND GROWER DIET FORMULATIONS

The compositions of broodstock and grower diets, prepared in dry and moist forms and recommended for use in the salmon aquaculture industry, are presented in Table 1. A detailed break down of the vitamin and mineral supplements added to these diets is given in Table 2.

Table 1. Compositions of Atlantic salmon broodstock and grower diets (expressed in %).

Ingredient[1]	Dry Feed		Moist Feed	
	Broodstock	Grower	Broodstock	Grower
Herring or capelin meal (min. 68% C.P.)	32.0	38.5	26.0	32.5
Feather meal, hydrolyzed (80% C.P.)	5.0	6.2	--	--
Soybean meal (48% C.P.)	8.0	8.5	--	--
Corn gluten meal (60% C.P.)	7.0	--	--	--
Poultry by-product meal (58% C.P.)	--	6.5	--	--
Brewers dried yeast (45% C.P.)	5.0	4.0	5.0	--
Wheat middlings (17% C.P.)	22.0	11.0	16.2	14.6
Wheat germ meal (25% C.P.)	--	--	5.0	--
Ground pasteurized fish (herring or capelin)	--	--	40.0	44.0
Whey, spray dried (12% C.P.)	7.0	9.0	--	--
Vitamin premix	1.6	1.5	1.3	1.4
Mineral premix	1.0	1.0	0.5	0.5
Herring or capelin oil	11.4	13.8	6.0	7.0
Calculated analysis				
Moisture	8.9	9.1	36.0	38.5
Protein	40.7	44.3	28.9	30.5
Lipid	15.2	19.1	10.8	12.5
Carbohydrate	20.9	16.4	13.8	9.2
Ash	6.9	7.7	5.1	5.8

[1] Crude protein content indicated as % C.P.

Table 2. Compositions of vitamin and mineral premixes for Atlantic salmon broodstock and grower diets. Ingredient quantities are expressed as mg/kg of diet unless stated otherwise.

Vitamins/Minerals	Dry Feed		Moist Feed	
	Broodstock	Grower	Broodstock	Grower
Vitamin A (I.U./kg of diet)[1]	9,000	6,000	7,500	5,000
Vitamin D3 (I.U./kg of diet)[1]	5,000	4,000	3,750	2,500
Vitamin E (I.U./kg of diet)[1]	375	350	300	250
Vitamin K	45	30	45	30
Thiamin (HCl)	50	40	75	50
Riboflavin	75	50	60	40
Pantothenic acid (as D-calcium salt)	225	150	180	120
Biotin	1	0.8	1.2	0.8
Folic acid	20	15	15	10
Vitamin B_{12}	0.06	0.03	0.05	0.03
Niacin	300	200	270	180
Pyridoxine (HCl)	45	30	60	40
Ascorbic acid	1,000	800	1,200	1,000
Chlorine chloride[2] (g/kg of diet)	2	1.5	2	1.5
DL-methionine	0.2	0.2	--	--
Inositol	400	400	400	300
Carophyll pink and/or red[3]	+	+	+	+
Iodine	7.5	5	7.5	5
Manganese	100	75	100	75
Iron	80	--	50	--
Zinc	140	115	120	100
Copper	20	--	15	--

1 International units per kg of diet.
2 Added as a separate supplement.
3 Quantity added varies with the supplement used and as specified by the manufacturer of the supplement.