N A S C O

NORTH AMERICAN COMMISSION

PROTOCOLS FOR THE INTRODUCTION AND TRANSFER OF SALMONIDS

by

NAC/NASCO Scientific Working Group

on Salmonid Introductions and Transfers

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PROTOCOLS FOR THE INTRODUCTION AND TRANSFER OF SALMONIDS IN THE NORTH AMERICAN COMMISSION AREA

INTRODUCTION

There is an increasing interest to introduce or transfer non-indigenous species, stocks and/or strains of salmonids for aquaculture, restoration of historic populations and/or improvement of recreational fisheries. The North American Commission (NAC) of the North Atlantic Salmon Conservation Organization (NASCO) recognizes the potential for adverse fish health, genetic and ecological effects on Atlantic salmon stocks via introductions and transfers of salmonids. These introductions or transfers pose an undue and irreversible risk to wild Atlantic salmon populations if adequate safeguards are not taken. The NAC, at its ninth annual meeting, June 1992, adopted protocols and guidelines for the introduction and transfer of salmonids, as contained in this report, for use in the North American Commission Area. The fundamental objectives of these protocols are:

(a) To minimize the risk of introduction and spread of infectious disease agents (fish health);

(b) To prevent the reduction in genetic diversity and prevent the introduction of non-adaptive genes to wild Atlantic salmon populations (genetics); and

(c) To minimize the intra- and inter-specific impacts of introductions and transfers on Atlantic salmon stocks (ecology).

This Report is divided into four parts: Part I provides a brief systematic summary of the Fish Health, Genetic, and Ecological Protocols, which are detailed in Part II, Part III, and Part IV respectively. Part I also introduces a Zoning concept for application of the protocols.

The standards adopted are considered minimal. Agencies may upgrade these if there is scientific justification, or if management needs to have greater assurance that biological characteristics of the current population will be conserved and protected.

These protocols will be reviewed every two years and amended as necessary by the Contracting Parties.

PART I

SUMMARY OF PROTOCOLS BY ZONE

by

NAC/NASCO Scientific Working Group on
Salmonid Introductions and Transfers

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1 ZONING OF RIVER SYSTEMS

The NAC has adopted the concept of Zoning for application of these protocols to the NAC Area. Three zones have been designated based on the degree of degradation or manipulation of the wild Atlantic salmon populations (Figure 1). The NAC recognizes that Atlantic salmon populations have been variously affected by human activities. These activities include over-harvesting, selective fishing, habitat degradation, mixing of stocks, introduction of non-indigenous fish species, and spreading fish diseases. Atlantic salmon stocks in northern areas (Zone I) have generally been least affected, and those stocks in the southern area (Zone III) have been most affected, by humans.

In order to allow operational flexibility within a Zone, river systems have been classified as Class I, II, or III rivers. Generally, rivers will have the same classification as the Zone in which they occur. For example, in Zone II, river systems will be mainly categorized as Class II. However, a river system may be assigned a higher classification than the Zone in which it is located (e.g., Class I river in Zone II) to allow additional protection for valuable Atlantic salmon stocks. In extenuating circumstances and if a river is sufficiently isolated from other rivers, it is acceptable to have a river with a lower classification than the Zone in which it is located (e.g., Class III rivers within Zone II or Class II rivers in Zone I).

All rivers are presently classified at the same level as the Zone designation. Member countries wishing to change the location of Zone boundaries or to have rivers of a lower classification within a Zone should submit their recommendations, with scientific justifications, to NAC.

2 DESCRIPTION OF ZONES

<u>Zone I</u>: Geographic Area: Northern Quebec, Labrador, Newfoundland (west coast) and Anticosti Island.

Rivers are classified primarily as Class I. They are pristine rivers with no significant man-made habitat alterations, no history of transfers of fish into the watersheds, and no fish rearing operations in the watersheds.

<u>Zone II</u>: Geographic Area: Quebec rivers flowing into Gulf of St. Lawrence south of Pte. des Monts, Gaspé region of Quebec, Magdalen Islands, Prince Edward Island, New Brunswick, Nova Scotia, Newfoundland (except west coast), St. Pierre and Miquelon Islands, and State of Maine east of Rockland.

Rivers are classified primarily as Class II watersheds in which one or more of the following conditions occur: the habitat has been altered; non-indigenous wild or hatchery-reared Atlantic salmon stocks have been released; or aquaculture has been conducted in marine cage culture. Non-indigenous species may be present in land-based facilities. Introduced species such as rainbow trout would be treated as indigenous if a population has been established for ten or more years.

Zone III: Geographic Area: Lake Ontario, southern Quebec draining to St. Lawrence River, State of Maine west of Rockland, New Hampshire, New York, Connecticut, Massachusetts, New Jersey, Rhode Island, and Vermont.

Rivers are classified primarily as Class III watersheds in which habitats have been altered, or where fish communities are destabilized, or exotic species are present.

3 PROTOCOLS

3.1 Protocols applicable to all three Zones

(1) Reproductively viable strains of Atlantic salmon of European origin, including Icelandic origin, are not to be released or used in Aquaculture in the North American Commission Area. This ban on importation or use of European-origin Atlantic salmon will remain in place until scientific information confirms that the risk of adverse genetic effects on wild Atlantic salmon stocks is minimal.

(2) No live salmonid fishes, fertilized eggs, gametes, or fish products are to be imported from IHN enzootic areas, unless sources have an acceptable history of disease testing demonstrating the absence of IHN (e.g. Great Lakes Fish Health Disease Committee protocol requirements). IHN infected areas currently include State of Washington, Oregon, Idaho, California, Alaska, British Columbia, Japan, and parts of Taiwan and France.

(3) Prior to any transfer of eggs, juveniles or brood stock a minimum of three health inspections of the donor facility will be undertaken during the two-year period immediately preceding the transfer; and the inspections must reveal no evidence of either emergency or restricted fish pathogens in the donor population (see Part II).

(4) Prior to any movement of non-native fishes into a river system or rearing site inhabited by Atlantic salmon the agency with jurisdiction shall review and evaluate fully the potential for interspecific competition which would adversely impact on the productivity of wild Atlantic salmon populations. Such evaluations should be undertaken, to the extent possible, with information on the river in which the introduction is to occur and from similar situations.

(5) Hatchery rearing programs to support the introduction, re-establishment, rehabilitation and enhancement of Atlantic salmon should try to comply with the following measures:

   (a) Use only F1 progeny from wild stocks;

   (b) Derive broodstock from all phenotype age-groups and the entire run of a donor population;

(c) Avoid selection of the "best" fish during the hatchery rearing period; and

(d) During spawning, make only single paired matings from a broodstock population of no less than 100 parents. Should the number of one sex be fewer than 50, the number of spawners of the other sex should be increased to achieve a minimum effective population size (N_e) of 100.

$$N_e = \frac{4N\_N\_}{N\_+N\_}.$$

3.2 Protocols applicable to Zone I

Zone I consists of Class I watersheds where every effort must be made to maintain the existing genetic integrity of Atlantic Salmon stocks. The following summary protocols apply.

3.2.1 General within Zone I

- No Atlantic salmon reared in a fish culture facility are to be released into a Class I river, another river which has its estuary less than 30 km from a Class I river, or a marine site less than 30 km from a Class I river (distances would be measured in a straight line(s) headland to headland).

- No non-indigenous fish species or Atlantic salmon stock is to be introduced into a Class I watershed.

3.2.2 Rehabilitation

- Fisheries management techniques will be used to ensure sufficient spawners such that spawning escapement exceeds a minimum target level to maintain an effective breeding population.

- Habitat that becomes degraded will be restored to the greatest extent possible.

3.2.3 Establishment or re-establishment of Atlantic salmon in a river or part of a watershed where there are no salmon

- Use transfers of adults or juvenile salmon from the residual population in other parts of the watershed.

- A nearby salmon stock which has similar phenotypic characteristics to the lost stock could be transferred if there is no residual stock in the recipient watershed and provided an effective breeding population is maintained in the donor watershed (See Section 3.1 (5)).

- If the biological characteristics of the original stock are not known or there was no previous stock in the recipient watershed, then transfer broodstock or early life stages from a nearby river having similar habitat characteristics.

3.2.4 Aquaculture

(i) Rearing in marine or freshwater cages, or land-based facilities:

- Rearing of salmonids or non-indigenous fish at locations in the marine environment, in a Class I river, or in a watershed with its estuary less than 30 km (measured in a straight line(s) headland to headland) from the estuary of a Class I river is not permitted except in land-based facilities using reproductively sterile fish, or reproductively viable indigenous fish species such as brook trout or arctic charr;

- Rearing of salmonids at locations in the marine environment, or in a watershed with its estuary greater than 30 km (measured in a straight line(s) headland to headland) from Class I rivers is permitted in either sea cages or land-based facilities with reproductively sterile fish or with brook trout or arctic charr provided that the risk of adverse effects on wild Atlantic salmon stocks is minimal.

(ii) Commercial ranching:

- No commercial ranching of salmonids is permitted within 30 km of the estuary of a Class I river (measured in a straight line(s) headland to headland);

- At locations greater than 30 km from the estuary of a Class I river, reproductively sterile Atlantic salmon, reproductively viable brook trout or Arctic charr, and reproductively sterile non-indigenous species may be ranched provided that the risk of adverse effects on wild Atlantic salmon stocks are minimal.

3.3 Protocols applicable to Zone II

3.3.1 General within Zone II

- Reproductively viable non-indigenous species and reproductively viable Atlantic salmon stocks non-indigenous to the NAC area are not to be introduced into watersheds or into the marine environment of Zone II.

- Restoration, enhancement and aquaculture activities are permitted in the freshwater and marine environments.

3.3.2 Rehabilitation

- The preferred methods are to improve degraded habitat and ensure escapement of sufficient spawners through fisheries management.

- If further measures are required, use residual stocks for rehabilitation and enhancement. If the residual stock is too small, select a donor stock having similar life history and biochemical characteristics from a tributary or nearby river.
- Stocking of hatchery-reared smolts is preferred, to reduce competition with

juveniles of the natural stocks.

3.3.3 Establishment or re-establishment of Atlantic salmon in a river or part of a watershed where there are no salmon

- To establish an Atlantic salmon stock, use a stock from a nearby river having similar stream habitat characteristics.

- If re-establishing a stock, use a stock from a nearby river which has similar biological characteristics to the original stock.

- It is preferable to stock rivers with broodstock or early life history stages (eggs and fry); this would allow selection and imprinting by juveniles to occur.

- If eggs are spawned artificially, use single pair matings and optimize the effective number of parents (See Section 3.1(5)).

3.3.4 Aquaculture

(i) Rearing in marine or freshwater cages, or land-based facilities:

  - It is important to apply methods which minimize escapes;

  - Develop domesticated broodstock using local stocks; or, if local stocks are limited, use nearby stocks;

  - Reproductively viable non-indigenous species may only be introduced into land-based facilities where risk of escapement is minimal;

  - Non-indigenous stocks may be introduced into the wild or used in cage rearing operations if the fish are reproductively sterile and the risk of adverse ecological interactions is minimal.

(ii) Commercial ranching:

  - Commercial Atlantic salmon ranching will only be permitted at release sites located greater than 20 km from the estuary of a Class II river (measured in a straight line(s) headland to headland) and it is demonstrated that the activity will not negatively affect wild Atlantic salmon stocks;

  - Non-indigenous species or distant national Atlantic salmon stocks may be used if the fish are reproductively sterile and the risk of adverse ecological interactions in minimal.

3.4 Protocols applicable to Zone III

3.4.1 General within Zone III

- Indigenous and non-indigenous salmonid and non-salmonid [except reproductively viable Atlantic salmon stocks non-indigenous to the NAC Area] fishes may be considered for introduction or transfer if fish health and genetic protocols are followed and negative impacts on Atlantic salmon can be shown to be minimal using careful ecological impact evaluation.

3.4.2 Rehabilitation

- Habitat quality should be upgraded wherever possible.

- Rebuilding stocks can be achieved by controlling exploitation and by stocking cultured fish.

3.4.3 Establishment or re-establishment of Atlantic salmon in a river or part of a watershed where there are no salmon

- Transfer source stocks from nearest rivers having similar habitat characteristics.

- Stock with juvenile stages (eggs, fry and/or parr). If eggs are spawned artificially, use single pair matings and optimize the effective number of parents (Section 3.1(5)).

3.4.4 Aquaculture

(i) Rearing in marine or freshwater cages, or land-based facilities:

  - Use of local stocks is preferred but non-indigenous stocks may be cultured;

  - Marine cage culture can be widely practised; but preferred locations are at least 20 km from watersheds managed for salmon production (measurements are by straight lines from headland to headland);

  - Culture of non-indigenous species in land-based facilities on Class III watersheds is permitted in adequately controlled facilities where risk of escapement is minimal.

(ii) Commercial ranching:

  - Commercial ranching of salmonids is permitted if it is demonstrated that the activity will not negatively affect Atlantic salmon rehabilitation or enhancement programs or the development of wild Atlantic salmon stocks;

4 GUIDELINES FOR APPROVAL OF INTRODUCTIONS AND TRANSFERS

Both proponents and agencies responsible for managing salmonids have a responsibility for ensuring that risk of adverse effects on Atlantic salmon stocks from introductions and transfers of salmonids and other fishes is low. Reasonable laws to protect wild stocks should be enacted by each agency, as necessary. Resource management agencies will determine protection for habitats with Atlantic salmon potential.

4.1 Responsibility of proponent

The proponent must submit an application for introduction or transfer of fishes to the permit-issuing agency. This request must provide a full justification for the introduction or transfer such that a complete evaluation will be possible prior to issuance of a permit. The list of information to be included in the justification for introductions and transfers is in Section 4.4 below. The lead time required for notice and justification of introductions and transfers will be determined by the permit-issuing agency. Proponents should be aware of the protocols established for introductions and transfers.

4.2 Responsibility of government agencies having the authority to issue permits

These agencies shall be those entities having the responsibility for fishery management within the receiving area. The responsibilities of the agencies shall include:

(1) Establish, maintain, and operate a permit system and inventory for all introductions and transfers of fishes;

(2) Enact regulations required to control the introductions and transfers of fishes as per established protocols;

(3) Establish a formal scientific evaluation process to review all applications (private and government agencies) for the introduction and transfer of all species and recommend conditional acceptance or rejection of the proposed introductions and transfers based on the potential impact on the productivity of Atlantic salmon;

(4) Within the Zones each agency may be more restrictive in classifying individual watersheds. Rarely, a less restrictive classification may be applied to an individual watershed if its estuary is at least 30 km in Zone I, or 20 km in Zone II (measured in straight lines headland to headland) from a watershed with a higher classification;

(5) Annually, submit to the NAC Scientific Working Group the results of the permit submission/review process, and a list of introductions and/or international transfers proposed for their jurisdiction;

(6) Prevent the release of fishes which will adversely affect the productivity of wild Atlantic salmon stocks.

4.3 Responsibilities of the NAC Scientific Working Group on Salmonid Introductions and Transfers

(1) Maintain an inventory of all introductions of salmonids, transfers of salmonids from IHN-infected areas, and importation of salmonids across national

boundaries into the Commission Area.

(2) Review and evaluate all introductions and transfers referenced in Section 4.3(1) above in relation to the NAC protocols and report the results to the North American Commission.

4.4 Preparation of proposals

The following information is required, by the permit-issuing agency, with applications involving introductions and transfers of salmonids, except for restocking into source river. This information will be used to evaluate the risk of adverse effects on Atlantic salmon stocks.

(1) Name the species, strain and quantity to be introduced or transferred, and include:

(a) Time of introduction or transfer;

(b) List anticipated future introductions or transfers;

(c) List previous introductions and/or transfers.

(2) Area, place, river or hatchery from which the fish will be obtained.

(3) Proposed place of release and any interim rearing sites.

(4) Disease status of donor hatchery, river or other location from which fish are obtained.

(5) Disease status of recipient facility or stream (where available).

(6) Objectives of the introduction or transfer and the rationale for not using local stock or species.

(7) For non-indigenous species, provide the available information on the proposed species' life history, preferred habitat, potential parasites and disease agents, and potential for competition with Atlantic salmon in the recipient waters or nearby waters.

(8) Information on similar transfers or introductions.

(9) Proposed procedure for transportation from donor to recipient site.

(10) List measures to be taken to prevent transmission of disease agents and to reduce the risk of escape of fish.

(11) Species composition at proposed site of introduction and adjacent rivers.

(12) Climatic regime and water chemistry, including pH of waters at the site of proposed introduction and of adjacent rivers.

(13) For indigenous species determine the life history and biological characteristics of donor stock. This would include such characteristics as run timing, time of spawning, age-at-maturity, size-at-age etc.

(14) Potential of introduced or transferred fish to disperse to nearby streams.

(15) A bibliography of pertinent literature should be appended to the proposal.

4.5 Evaluation of proposals

The evaluation of proposals will be the responsibility of the permitting agency and will focus on the risk to Atlantic salmon production and potential production associated with the proposed introductions and/or transfers. The evaluation will be based on the classification of the recipient watershed. All requests for introductions or transfers must provide sufficient detail (Section 4.4 above) such that the potential risk of adverse effects to Atlantic salmon stocks can be evaluated.

The evaluation of potential adverse effects on fish health will consider the disease history of the donor and recipient facility and/or watershed with specific reference to the potential for transferring emergency diseases. The risk of detrimental genetic effects of introducing a non-indigenous stock into a river will be evaluated taking into consideration the phenotypic and life history characteristics of the donor stock, the biochemical information (mitochondrial/nuclear DNA and enzyme frequencies, if available), and geographic distance between donor and recipient locations. The evaluation of the risk of ecological effects on Atlantic salmon populations is more involved. Introduction of non-indigenous Atlantic salmon stocks and/or non-indigenous species will be evaluated by considering the life history and habitat requirements of the transferred fish.

The introduction of non-indigenous species poses a significant risk to the productivity of the Atlantic salmon stocks. Evaluation will be by comparison of the habitat requirement and behaviour of both the proposed introduced species and the indigenous Atlantic Salmon stock at all life stages. The habitat requirements and areas of possible interactions with Atlantic Salmon have been described for 13 fish species (see Part IV, Ecological Subgroup report). These can be used to provide a cursory evaluation of the life history stage at which interactions would occur. However, more detailed information on stocks and habitats in both donor and recipient locations would be required in the form of an envirogram (example is provided in Part IV). Where insufficient data are available, research will be required prior to permitting the introduction or transfer.

An outline example of the type of information which is available in the species summaries (Part IV) is presented below for rainbow trout:

(1) Conditions under which interactions may occur:

- spawning rainbow trout may overcut Atlantic salmon redds and displace developing eggs;

- competitive interaction of juveniles: (i) exploitative competition for food; and

(ii) interference competition;

- rainbow trout juveniles are more aggressive than juvenile Atlantic salmon, and may displace salmon from pools; and

- large rainbow trout are piscivorous and could prey on all stages of young salmon including emigrating smolts.

(2) Low interaction:

- in streams which Atlantic Salmon do not utilize;

- in streams in which salmon are well established; and

- aquaculture using sterile fish or land-based facility.

(3) Conditions under which no interaction would occur. It would be permissible to use reproductively viable rainbow trout:

- in habitats with pH less than 5.5;

- if rainbow trout are already present in recipient stream; and

- in disturbed ecosystems where Atlantic Salmon are absent and sport fishing would be improved.

5 GLOSSARY

Applicant: See proponent.

Aquaculture: The culture or husbandry of aquatic fauna other than in research, in hobby aquaria, or in governmental enhancement activities.

Commercial Ranching: The release of a fish species from a culture facility to range freely in the ocean for harvest and for profit.

Competition: Demand by two or more organisms or kinds of organism at the same time for some environmental resource in excess of the available supply.

Containment: Characteristic of a facility which has an approved design which minimizes operator error to cause escape of fish, or unauthorized persons to release contained fish.

Diversity: All of the variations in an individual population or species.
Enhancement: The enlargement or increase in number of individuals in a population by providing access to more or improved habitats or by using fish culture facility production capability.

Exotic: See introduced species.

Fish: A live finfish.

Fish culture facility: Any fish culture station, hatchery, rearing pond, net pen, or container holding, rearing, or releasing salmonids.

Gamete: Mature germ cell (sperm or egg) possessing a haploid chromosome set and capable of formation of a new individual by fusion with another gamete.

Genetics: A branch of biology that deals with the heredity and variation of organisms and with the mechanisms by which these are effected.

Indigenous: Existing and having originated naturally in a particular region or environment.

Introduced species: Any finfish species intentionally or accidentally transported or released by Man into an environment outside its native or natural range.

Introduction: The intentional or accidental release of a species into environment outside its native or natural range.

Isolation: Means restricted movement of fish and fish pathogens within a facility by means of physical barriers, on-site sanitary procedures and separate water supply and drain systems and cultural equipment.

Mariculture: Aquaculture in sea water.

Native: See indigenous.

N_e: Effective population size = $\frac{4N\_N\_}{N\_+N\_}$

Niche: A site or habitat supplying the sum of the physical and biotic life-controlling factors necessary for the successful existence of a finfish in a given habitat.

Non-indigenous: Not originating or occurring naturally in a particular environment; introduced outside its native or natural range.

Population: A group of organisms of a species occupying a specific geographic area.

Predator: An individual that preys upon and eats live fish, usually of another species.

Proponent: A private or public group which requests permission to introduce or transfer any finfish within or between countries and lobbies for the proposal.

Quarantine: The holding or rearing of fish under conditions which prevent the escape or movement of fish and fish disease agents. (For a detailed description of a quarantine facility see Annex IX of Part II).

Rehabilitation: The rebuilding of a diminished population of a finfish species, using a remnant reproducing nucleus, toward the level that its environment is now capable of supporting.

Restoration: The re-establishment of a finfish species in waters occupied in historical times.

Salmonid: All species and hybrids of the Family Salmonidae covered by the AFS checklist special publication No. 12, "A list of Common and Scientific Names of Fishes from the United States and Canada (1980)".

Species: A group of interbreeding natural populations that are reproductively isolated from other groups.

Stock: Population of organisms sharing a common gene pool which is sufficiently discrete to warrant consideration as a self-perpetuating system which can be managed.

Strain: A group of individuals with a common ancestry that exhibits genetic, physiological, or morphological differences from other groups as a result of husbandry practices.

Transfer: The deliberate or accidental movement of a species between waters within its native or natural geographic range, usually with the result that a viable population results in the new locations.

Transferred species: Any finfish intentionally or accidentally transported and released within its native or natural geographic range.

P A R T I I

PROTOCOLS ON SALMONID FISH HEALTH

by

The Fish Health Subgroup of
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Salmonid Introductions and Transfers

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1 INTRODUCTION

The development of fish health protocols is intended to protect wild stocks of Atlantic salmon in eastern Canada and the eastern United States from fish diseases that may be transmitted through the movement of introduced or transferred salmonid fish species. There is increasing pressure to introduce/transfer salmonid stocks for fisheries management and aquaculture purposes. The introductions/transfers could compromise the health status of existing stocks. Wherever possible, the use of local stocks should be encouraged and is preferred. However, where importation is necessary, the North American Commission (NAC) of the North Atlantic Salmon Conservation Organization (NASCO) has developed these "fish health protocols" to unify and coordinate the fish disease control efforts for its members.

2 DEFINITIONS

Cage culture facility: Any fish culture facility that is maintained in natural waters (either marine or fresh). Cages holding broodstock lots that are no closer than 2,000 feet upstream or downstream, or 1,000 feet across tide from adjacent production cages shall be considered as a separate cage culture facility.

Fish: Live fin fish, viable fish eggs (fertilized or unfertilized), viable sperm, offal or other fish products which have not been so processed as to render them incapable of transmitting a listed fish disease.

Fish culture facility: Any fish culture station, hatchery, rearing pond, net pen, or other container which holds, rears or releases salmonids using marine or fresh waters.

Free ranging fish: Includes wild fish and fish which have spent a part of their life cycle in a fish culture station and have been captured from the wild.

Introduced species (non-indigenous species): Any species intentionally or accidentally transported or released by Man into an environment outside its historical range.

Isolation: Means restricted movement of fish and fish pathogens within a facility by means of physical barriers, on-site sanitary procedures and separate water supply and drain systems and fish cultural equipment.

Listed diseases: Fish diseases as listed in Annex III.

North Atlantic Salmon Conservation Organization (NASCO): Inter-governmental organization established by the Convention for the Conservation of Salmon in the North Atlantic Ocean with the objective of contributing, through consultation and cooperation, to the conservation, restoration, enhancement and rational management of salmon stocks in the North Atlantic Ocean taking into account the best scientific evidence available to it.

North American Commission (NAC): Regional commission of NASCO covering maritime waters within areas of fisheries jurisdiction of coastal states off the east coast of North America.

Quarantine facilities: See Annex IX.

Salmonid: All species and hybrids of the family Salmonidae covered by the AFS checklist special publication No. 12, "A List of Common and Scientific Names of Fishes from the United States and Canada" (1980).

Transferred species (transplanted species): Any species intentionally or accidentally transported or released by man within that species' historical range.

3 BASIC OBLIGATIONS

- The agencies of member states/provinces of NASCO shall take all appropriate measures including the development of legislative authority and regulations, where necessary, to restrict the spread of listed fish diseases, to contain them within their known geographic ranges, and to strive for their elimination in accordance with the provisions of this program.

- Nothing in this program shall derogate from the right of the member agencies to apply additional measures of inspection, quarantine, and disease eradication for the control of fish diseases.

4 APPLICATION

The provisions of this program apply to:

- species and hybrids of the family Salmonidae;

- fish diseases as listed in Annex III;

- fish culture facilities;

- free ranging fish; and

- fish disease research and development facilities.

The provisions of this program shall not apply to:

- fish in transit through the NASCO region provided that no fish are removed from their original shipping containers and no water is discharged; and

- fish and/or specimens from fish imported or exported for purposes of diagnostic or inspection services and related laboratory tests as long as quarantine conditions can be maintained.

5 TRAFFIC IN FISH

For the purpose of this protocol, the terms introduce and/or transfer apply to the movements between state/provincial jurisdictions and not to intrajurisdictional movements. Canadian Fish Health Protection Regulations or United States Title 50 must be satisfied for any international or interprovincial movement of fish.

5.1 Fish transfers in areas not enzootic for infectious hematopoietic necrosis (IHN)

5.1.1 Fish culture facilities including movements to cage culture facilities

Salmonids may be introduced/transferred between fish culture facilities in areas not enzootic for IHN or released into the watersheds if the following provisions are met:

(a) The source fish culture facility must possess, and provide a copy to the receiving fish culture facility, a fish health inspection report (Annex I) issued by a fish health inspector (Section 7) in accordance with the protocol established in Section 6. An Exporter's Declaration (Annex II) must, in addition, be attached to the fish health inspection report;

(b) A minimum of 3 inspections must be conducted during the two-year period immediately preceding the transfer;

(c) No fish will be accepted if Emergency diseases (Annex III) are detected during the inspection period. Importations of fish from facilities with restricted diseases may be permitted provided this does not result in changing the receiving facility's disease status and meets with the requirements stated in the Guidelines for the Control and Management of Disease Agents (Annex V);

(d) At least one inspection for each listed disease, except as noted in Annex III, will be conducted on all lots of salmonids, regardless of age, prior to the transfer of eggs or the transfer or stocking of fish;

(e) A facility utilizing a pathogen-free water source can transfer fish following one successful inspection providing the source of stock for the facility was a facility free of listed diseases. The facility must meet the other above requirements, (a), (c) and (d).

5.1.2 Movements from cage culture facilities

Eyed salmonid eggs may only be introduced/transferred to fish culture facilities from brood stock reared in cage culture facilities in areas not enzootic for IHN if the following provisions are met:

- The source cage culture facility must possess, and provide a copy to the receiving fish culture facility a fish health inspection report (Annex I) issued by a fish health inspector (Section 7) in accordance with the protocol established in Section 6. An Exporter's Declaration (Annex II) must, in addition, be attached to the fish health inspection report;

- In the event that sexually maturing brood stock are temporarily transferred from a marine site to freshwater holding facilities for conditioning and spawning, the inspection requirement for all lots reared at the site remains unchanged;

- Movements of fertilized eyed eggs only will be allowed. Eggs must be water hardened in pathogen-free water, surface disinfected (Annex VII) following water hardening, incubated in pathogen-free water, surface disinfected again prior to transfer and upon receipt at the receiving fish culture facility;

- The fish health inspection of the broodstock must include lethal sampling, plus examination of reproductive fluids, of 100% of the broodstock used as parents for the eggs to be transferred;

- All lots of fish as well as brood stock reared at a cage culture site must be inspected. No eggs will be accepted if pathogens found in the brood stock are from the emergency classification. If pathogens of the restricted classification are detected, transfer must be based on the Guidelines for the Control and Management of Disease Agents (Annex V).

5.1.3 <u>Free-ranging fish</u>

Introductions/transfers of free-ranging fish in areas not enzootic for IHN into fish culture facilities or released into the watersheds must meet the following provisions:

- The source of the introduction/transfer must provide the receiving fish culture facility or appropriate agency a fish health inspection report (Annex I) issued by a fish health inspector (Section 7) in accordance with the protocol (Section 6);

- There must be a minimum of three fish health inspections during the two-year period of the free-ranging stock immediately preceding transfer. At least one of these inspections must have taken place during the natural spawning period for the source. Representative salmonid species and various age classes (juvenile to broodstock) should be examined;

- No fish will be accepted if emergency pathogens are detected. If restricted pathogens are detected, transfers must be based on the Guidelines for the Control and Management of Disease Agents (Annex V);

- For introduction into a fish culture facility the following protocol must, in addition, be completed:

  (i) Movements of fertilized eyed eggs only will be allowed. Eggs must be water-hardened in pathogen-free water, surface disinfected (Annex VII) following water-hardening, incubated in pathogen-free water in isolation, surface disinfected again prior to transfer and upon receipt at the receiving fish culture facility;

  (ii) There must be lethal sampling, plus examination of reproductive fluids, of 100% of the broodstock used as parents for the eggs to be transferred.

5.2 Transfer of fish from areas enzootic for infectious hematopoietic necrosis (IHN)

is prohibited

(i) No live salmonid fish, gametes, fertilized eggs, or fish products may be imported from the areas enzootic for Infectious Hematopoietic Necrosis Virus (currently Washington, Oregon, Idaho, California, Alaska, British Columbia, all of Japan, and parts of Taiwan and France) and/or facilities receiving salmonid fish, gametes, fertilized eggs, or fish products from areas enzootic for IHN Virus.

(ii) Facilities which have received live salmonid fish, gametes, fertilized eggs, or fish products from IHN enzootic areas can transfer fertilized eyed eggs (only) if the following conditions are met:

- The source fish culture facility must possess, and provide a copy to the receiving fish culture facility, a fish health inspection report (Annex I) issued by a fish health inspector (Section 7) in accordance with the protocol established in Section 6. An Exporter's Declaration (Annex II) and copies of fish health inspection reports covering the source(s) in areas enzootic for IHN to the intermediate facility must, in addition, be attached to the fish health inspection report;

- All lots of fish at the source must be tested annually and found negative for IHNV for a period of time equal to the age of the oldest spawning fish or for a minimum period of three consecutive years, whichever is the greatest;

- All lots, using the oldest age classes first, of sexually mature fish will be sampled at the 2% incidence level utilizing ovarian fluid and pellet collected at spawning time or from post-spawning fish. Reproductive fluids will be sampled from 100% of the broodstock used as parents for the eggs to be transferred;

- Kidney/spleen samples will also be collected at the 5% incidence level from post-spawning broodstock and from all lots of sexually immature fish;

- All cell cultures will be observed for 28 days or alternatively for 14 days, followed by a blind passage onto new cultures of the same cell line with incubation for a further 14 days;

- No fish will be accepted if emergency pathogens are detected. If restricted pathogens are detected, transfers must be based on the Guidelines for the Control and Management of Disease Agents (Annex V);

- Only properly disinfected eggs may be imported (Annex VII). The eggs will be disinfected again upon receipt according to this procedure at the receiving fish culture facility;

- Eggs are incubated in a pathogen-free water supply;

- Eggs are hatched and reared in a quarantine facility for 6 months after hatching and fry subjected to at least one fish health inspection.

5.3 Direct transfer of eyed eggs from areas outside North America and not enzootic for infectious hematopoietic necrosis virus (IHN)

Eyed salmonid eggs may only be introduced/transferred to fish culture facilities if the following provisions are met:

- The source fish culture facility must possess, and provide a copy to the receiving fish culture facility, a fish health inspection report (Annex I) issued by a fish health inspector (Section 7) in accordance with the protocol established in Section 6. An Exporter's Declaration (Annex II) must, in addition, be attached to the fish health inspection report;

- A minimum of three (3) consecutive annual fish health inspections shall be conducted on all lots of fish;

- A fish health inspection of the broodstock must be conducted. There must be lethal sampling, plus examination of reproductive fluids, of 100% of the broodstock used as parents for the eggs to be transferred;

- Eggs must be water-hardened in pathogen-free water, surface disinfected (Annex VII) following water-hardening, incubated in pathogen-free water in isolation, surface disinfected again prior to transfer and upon receipt at the receiving fish culture facility;

- No eggs will be accepted if pathogens from the emergency classification are detected. Eggs from facilities with restricted diseases may be permitted provided this does not result in changing of the receiving facility's disease status and meets with the Guidelines for the Control and Management of Disease Agents (Annex V);

- Eggs are to be hatched and fish reared in a quarantine facility for 6 months after hatching and fry subjected to at least one fish health inspection prior to release.

6 FISH HEALTH INSPECTION REPORTS

(i) Fish health inspection reports of listed fish diseases (Annex III) shall be reported in the form prescribed in Annex I.

(ii) A fish health inspection report may only be issued by fish health inspectors as described in Section 7.

(iii) The most recent fish health inspection must have been conducted according to the procedures recognized in Annex IV and have occurred within <u>one year</u>. There must not have been any introductions of fish into that source since the last inspection.

(iv) Where introduction of fish has been made since the last inspection, complete fish health documentation of the source(s) of introductions (as described in this protocol) will be required.

7 FISH HEALTH INSPECTORS

(i) No owner, immediate family member or employee may serve as fish health inspector or may collect samples as part of a fish health inspection of a commercial or private facility in order to avoid any real or perceived conflicts of interest.

(ii) Competence of fish health inspectors shall be based upon standards set forth by the Fish Health Section of the American Fisheries Society or Canadian Fish Health Protection Regulations.

(iii) Fish health inspectors shall have, or have access to, adequate laboratory facilities and qualified personnel to assure the prompt and accurate conduct of inspections and diagnoses under the procedures set forth in "Procedures for the Detection and Identification of Certain Fish Pathogens," developed by the Fish Health Section (FHS) of the American Fisheries Society or the "Fish Health Protection Regulations Manual of Compliance" of the Department of Fisheries and Oceans, Canada.

8 ACKNOWLEDGMENTS

The NAC/NASCO Fish Health Guidelines were developed by the NAC/NASCO Scientific Working Group's Subcommittee on Salmonid Fish Health.

We want to extend our most sincere appreciation to all those who contributed to this international cooperative effort. These guidelines would never have reached fruition without their unselfish dedication to this process.

FISH HEALTH INSPECTION REPORT

Fish Source	Address or Location	Name of Owner or Manager	Type of Fish Examined:	Inspection Dates: Status[1]
			Hatchery ________ Sea Cage ________ Free Ranging_____	This ____________ ____________ Prior ____________ ____________ Prior ____________ ____________ ________________________ ________________________
		Telephone Number		

Water Supply:
Fresh Water ____ Lake/Impoundment ____ Spring ____ Enclosed ____ Open ____ Free of fish ____ Salt Water ____
Sea ____ Well ____ Stream ____ Sand Filter ____ Microsieve Filter ____ UV Treatment ____ Other ____

Fish Examined						Pathogens[5] Inspected For Methods[6] and Results[7]										
Species[2]	Lot Number	Age[3]	Number in Lot	Obtained as Eggs (E) or Fish (F) from:	Sample[4] Data	VP	VH	VE	BF	BR	BK	SW				

Footnotes: See other side of sheet for explanation of coding.	Samples Collected by:
Notes:	Name Affiliation Telephone

	Inspecting Biologist Signature Name and Title Address .... Telephone

FOOTNOTES:

1. The fish disease status system providing the abbreviation of the various pathogens should provide a clear understanding of the occurrence of designated fish pathogens in this facility/population for each inspection period and historically for previous 4 inspections.

2. Species Abbreviations:

ARC	- Arctic Charr	HYS	- Hybrid Salmonid (specify cross)
ARG	- Arctic Grayling	KOE	- Kokanee
ATS	- Atlantic Salmon	LAS	- Landlocked Atlantic Salmon
BKT	- Brook Trout	LAT	- Lake Trout
BNT	- Brown Trout	OHT	- Ohrid Trout
CHS	- Chum Salmon	OSA	- Other salmonid (specify)
COS	- Coho Salmon	PKS	- Pink Salmon
CKS	- Chinook Salmon	RBT	- Rainbow Trout
CUT	- Cutthroat Trout	SOS	- Sockeye Salmon
DOV	- Dolly Varden Trout	STT	- Steelhead Trout
GIT	- Gila Trout	SNT	- Sunapee Trout
GOT	- Golden Trout	WHF	- Whitefish (specify)

3. In lots of fish less than two years old, the age in months is expressed numerically. In lots two years old or older, the age in years is expressed in Roman numerals. ADM denotes broodstock of mixed ages.

4. When samples are collected on separate dates as part of a seasonal fish health inspection, the dates should be noted.

5. Findings are reported as the number of fish examined over the method used (see footnote 6) over the results.

Pathogen Abbreviations:

VP Infectious Pancreatic Necrosis virus*
VH Infectious Hematopoietic Necrosis virus*
VE Viral Hemorrhagic Septicemia virus*
VEN Viral Erythrocytic Necrosis
HPV Herpesvirus salmonis
OMV Oncorhynchus masou virus
YTV Yamame Tumor virus
BF Furunculosis (Aeromonas salmonicida)*
BR Enteric Redmouth (Yersinia ruckeri)*
BK Bacterial Kidney Disease (Renibacterius salmoniarum)*
BMA Motila Aeromonad Septicemia (Aeromonas hydrophila complex)
BP Pseudomonad Septicemia (Pseudomonas spp.)
BV Vibriosis (Vibrio salmonicida)
BVS Hitra Disease (Vibrio salmonicida)
BC Columnaris Disease (Flexibacter columnaris)
SW Whirling Disease (Myxobolus cerebralis)*
SC Ceratomyxosis (Ceratomyxa shasta)
SP Proliferative Kidney Disease (PKX)
* Designated fish pathogens

Any history of pathogens or disease syndromes diagnosed in this facility/population should be reported in the notes.

6. Diagnostic Methods:

VIRAL DISEASES: The methods employed are designated by a three or four letter and digit code. The first letter of the code represents the sampling method (see Sample Methods). The middle number(s) represents the cell line(s) used. The last letter represents the sample pooling scheme.

Sample Method:

A Whole fry homogenates
B Whole viscera homogenates
C Visceral homogenates (kidney/spleen)
D Ovarian fluids
E Other ____________________

Cell Line(s) - give incubation temperature in the notes:

1 RTG-2 (rainbow trout gonad)
2 CHSE (chinook salmon embryo)
3 FHM (fathead minnow)
4 EPC (epithelioma papillosum cyprini)
5 BF-2 (bluegill fry)
6 Other ____________________

Sample Pooling:

A Individual fish
B 5-fish pools
C Other ____________________

Whirling Disease Detection: Indicate material sampled in the notes: A single letter code denotes the method used as follows:

A Pepsin/trypsin digestion method
B Plankton centrifuge method
C Other ____________________

BACTERIAL DISEASES: The methods employed are designated by a three or four letter and digit code. The first letter of the code represents type of fish sampled (see below). The middle number represents the material sampled. The last letter(s) represents the techniques used:

Type of Fish Sampled:
A Live, healthy fish
B Moribund, diseased fish
C Mortalities
D Other ____________

Material Sampled:
1. Kidney
2. Hindgut
3. Lesion
4. Gill
5. Ovarian fluid
6. Seminal fluid
7. Other ____________________

Techniques: Indicate incubation temperature under Notes:

Primary isolation: A. Standard culture media (TSA/BHIA)
B. Cytophaga agar culture for myxobacteria
C. BKD culture (Evelyn)
D. Other

Presumptive diagnosis
E. Gram staining of kidney smears (BKD only)
F. Standard methods of physical and bio-chemical differentiation

Confirmatory diagnosis
H. Slide agglutination
I. Direct fluorescent antibody technique (DFAT)
J. Indirect fluorescent antibody technique (IFAT)
K. Enzyme-linked immunosorbent assay (ELISA)
L. Other

7. The results are notes as either + (positive) or - (negative).

ANNEX II

EXPORTER'S DECLARATION

____

Name of Source | Address | Name of Owner or Manager

Telephone Number

____

I declare that this shipment of ____
Number Species
[ ] eggs [ ] live fish is derived solely from this facility and that no fish, gametes, or fertilized eggs have been introduced into the above-named source since the last fish health inspection was done on ______________________ by ______________________________________.
Date Fish Health Inspector

If any fish, gametes, or fertilized eggs have been introduced to the above-named source since this last fish health inspection, they came from ____________________________________,
Name of Source

____, on ____________________,
Address Date

and were inspected by ____.
Fish Health Inspector

A copy of this health inspection report is appended.

The following is a list of therapeutic chemicals, antibiotics, bacterins and vaccines used at the source within the past year along with the dosages and dates applied.

____
____
____
____
____
____
____
____

The fish eggs in this shipment will be treated in formalin at 2000 mg/l for 15 minutes, thoroughly rinsed in pathogen-free well water or ultraviolet (UV) light sterilized water and then disinfected in PVP iodine (Wescodyne, Betadine, Argentyne, Buffodyne, etc.) at 100 mg/l active ingredients for 10 minutes and thoroughly rinsed again in pathogen-free water immediately before packing for shipment. (Disinfections are described in Annex VII.)

Date Signature

ANNEX III

LIST OF DISEASE AGENTS COVERED BY THE FISH HEALTH PROTOCOL FOR THE INTRODUCTION/TRANSFER OF SALMONIDS

Emergency

Those diseases which have not been detected within waters east of the Continental Divide or have had limited distribution:

(1) VHS - Viral Hemorrhagic Septicemia Virus
(2) IHN - Infectious Hematopoietic Necrosis Virus (Rhabdo-virus)
(3) Filterable agents - capable of causing cytopathic effect (CPE) in appropriate fish cell lines (with the exception of Infectious Pancreatic Necrosis Virus, IPN)
*(4) Ceratomyxosis (Ceratomyxa shasta)
*(5) PKD - Proliferative Kidney Disease agent
(6) Whirling Disease (Myxobolus cerebralis)

Restricted

Those diseases currently present east of the Continental Divide, but whose geographic range is limited. Every appropriate action should be taken to further reduce their range.

(1) IPN - Infectious Pancreatic Necrosis Virus (Birnavirus)
(2) BKD - Bacterial Kidney Disease (Renibacterium salmoninarum)
(3) Furunculosis (Aeromonas salmonicida)
(4) ERM - Enteric Redmouth (Yersinia ruckeri)

*Other diseases that are recognized as potentially major diseases:

(1) Hitra Disease (Vibrio salmonicida)
(2) Viral erythrocytic necrosis (viral)
(3) Lake trout agent (suspect herpesvirus)
(4) Pancreas disease (unknown)
(5) Oncorhynchus masou virus (Herpesvirus)
(6) Lake trout coldwater disease (Cytophaga psychrophila)

Any other pathogen/parasite identified must be reported and considered prior to approval of any introduction/transfer.

*Inspections in areas not enzootic for Ceratomyxosis (Ceratomyxa shasta) Proliferative Kidney Disease agent (PKD) need not include these diseases unless there have been known importations of fish or eggs from enzootic areas.

ANNEX IV

METHODS OF DIAGNOSIS

A. The "Procedures for the Detection and Identification of Certain Fish Pathogens," developed by the Fish Health Section (FHS) of the American Fisheries Society or the "Fish Health Protection Regulations Manual of Compliance" of the Department of Fisheries and Oceans, Canada provide the basis for the work supporting fish culture facility inspections. Annex IV, Section B provides procedural changes incorporated into the program by the NAC. If more sensitive or more definitive published procedures are available, they may be used in addition provided they are noted on all associated inspection reports. Other procedural changes may be incorporated into the program by the NAC as appropriate and will be listed in Annex IV, Section B.

B. <u>Renibacterium salmoninarum</u>

1. When fluorescent antibody techniques (direct or indirect) are employed for examining samples using techniques in reference listed above, a minimum of 50 fields using 1000X magnification per slide must be examined.

   A slide represents 1 fish

   50 fields/slide
   5 organisms per slide will be defined as positive if there have been no clinical signs of the disease.

2. Examination of reproductive fluids of broodstock used as parents

   Routine screening:

   Males: At the time of milt collection all males will be examined for the presence of overt kidney disease lesions. If males are suspected of or diagnosed as having overt BKD, the milt from these fish should be discarded.

   Females: At the time of egg collection all females will be examined for the presence of overt kidney disease lesions. If females are suspected of or diagnosed as having overt BKD, the eggs from these fish are to be discarded. All females which appear normal are to be screened by examining centrifuged ovarian fluid by DFAT or IFAT. Only eggs from females with negative IFAT or DFAT are to be hatched. All other eggs are considered to be positive and are to be discarded.

Procedure:

OVARIAN FLUID

Collection

Two mls of ovarian fluid are immediately placed into a sterile labelled centrifuge tube. Samples should be kept on ice and processed as soon as possible. (The time between sample collection and assay should not exceed 72 hours.)

Centrifugation

Homogenized (optional) samples are centrifuged 1500g for 15 min. at 4°C. The supernatant is decanted and the pellet resuspended in the remaining fluid (if the resuspended pellet is too concentrated, PBS can be used to dilute it.)

IFAT, DFAT

A smear is prepared on a clean slide and stained according to standard techniques. A minimum of 50 fields using 1000X magnification is to be read. Positive controls from either ovarian fluid or other positive tissue are to be used with each set of slides being prepared.

ANNEX V

GUIDELINES FOR THE CONTROL AND MANAGEMENT OF DISEASE AGENTS

Emergency Diseases

These diseases have not, or only on a limited basis, been detected in the waters of NASCO region. No salmonids, gametes or fertilized eggs from any source, unless the source has been regularly inspected and found to have a history of freedom from the following diseases for the past 2 years*, shall be imported to areas not enzootic for Infectious Hematopoietic Necrosis. In the event any of the following disease agents is confirmed in any fish population under propagation, immediate steps shall be initiated to eradicate this disease from the facility and adjacent water as authorized by the member agency with jurisdiction (Annex VIII):

(1) Viral Hemorrhagic Septicemia (VHS) Virus

(2) Infectious Hematopoietic Necrosis (IHN) Virus*

(3) Whirling Disease, Myxobolus cerebralis

Disinfected eggs (Annex VII) and spore-free transport water of well origin may be transferred to facilities without altering the disease status of the receiving station (Annex VI).

(4) Ceratomyxosis, Ceratomyxa shasta

(5) Proliferative Kidney Disease Agent (PKD)

Restricted Diseases

Those diseases currently present east of the Continental Divide. Every appropriate action should be taken to reduce their range.

(1) Infectious Pancreatic Necrosis (IPN) Virus

No salmonid gametes, fertilized eggs, or fish from IPN positive facilities shall be transferred to facilities where IPN virus has not been detected within the past two years.

(2) Bacterial Kidney Disease (BKD), Renibacterium salmoninarum

No salmonid gametes, fertilized eggs or fish from BKD positive fish stocks or facilities shall be transferred to facilities where BKD has not been positively detected within the past two years.

*Under no circumstances will salmonids, gametes or fertilized eggs be imported from areas enzootic for IHN.

(3) Furunculosis, Aeromonas salmonicida

No salmonids from furunculosis positive facilities shall be transferred to facilities where furunculosis has not been detected within the past two years. Disinfected eggs (Annex VII) and transport water may be transferred to facilities without altering the disease classification of the receiving station (Annex VI).

(4) Enteric Redmouth (ERM), Yersinia ruckeri

No salmonids from ERM positive facilities shall be transferred to facilities where ERM has not been detected within the past two years. Disinfected eggs (Annex VII) and transport water may be transferred to facilities without altering the disease status of the receiving station (Annex VI).

Other

Other diseases that are recognized as potentially major diseases:

(1) Hitra Disease - Vibrio salmonicida
(2) Viral erythrocytic necrosis (viral)
(3) Lake trout agent (suspect herpesvirus)
(4) Pancreas disease (unknown)
(5) Oncorhynchus masou virus (Herpesvirus)
(6) Lake trout coldwater disease - Cytophaga psychrophila

In the event of the detection of these potentially major diseases, the pathogen must be reported and considered prior to approval.

ANNEX VI

FISH CULTURAL FACILITY DISEASE STATUS

A. LISTED DISEASES

Each cultural facility rearing salmonids and each salmonid spawning population, whether wild or domesticated, will be inspected for the following:

	DISEASE OR AGENT	ABBREVIATION
1.	Viral Hemorrhagic Septicemia (VHS) Virus	VE
2.	Infectious Hematopoietic Necrosis(IHN) Virus	VH
3.	Infectious Pancreatic Necrosis(IPN) Virus	VP
4.	Bacterial Kidney Disease(BKD) R. salmoninarum	BK
5.	Furunculosis A. salmonicida	BF
6.	Enteric Redmouth(ERM) Y. ruckeri	BR
7.	Whirling Disease M. cerebralis	SW
*8.	Ceratomyxosis, C. shasta	SC
*9.	Proliferative Kidney Disease (PKD)	SP

B. STATUS

The status of a fish cultural or cage facility and of free-ranging populations is assigned following the identification of any listed disease in any fish lot in the population. The status is represented by the abbreviation of the listed disease.

C. RESTRICTIONS

No shipments of fish or eggs will be made that will downgrade the status of the receiving facilities. Shipments of fish or eggs between facilities will be governed by the disease status of the facilities or fish populations involved.

*Inspection in areas not enzootic for Ceratomyxosis (C. shasta) and Proliferative Kidney Disease (PKD) need not include these diseases unless there have been known importations of fish from enzootic areas.

ANNEX VII

EGG DISINFECTION

All fish culture facilities receiving eggs will properly disinfect these eggs as per the following:

PROCEDURE FOR IODINE AND FORMALIN EGG DISINFECTION

1. Disinfect in any area away from the fish culture station, where contaminated water and/or eggs can be isolated from fish or eggs already on the facility.

2. Place eggs into netting suspended in a tub of water. Allow eggs to water-harden for 30-60 minutes if freshly fertilized or shipped in air. Add oxygen with an airstone if necessary.

3. Transfer drained eggs with the netting to a second tub containing 2000 ppm formalin solution for 15 minutes (disinfect the netting also).

   Prepare the formalin bath using the following concentration:

   7.5 ml formalin per gallon water

4. After 15 minutes transfer eggs to third tub of pathogen-free water and allow to rinse.

5. Transfer drained eggs with the netting to a fourth tub containing 100 ppm iodine solution for 10 minutes (disinfect the netting also).

   Prepare iodine bath using one of the following:

   Argentyne -- 38 ml Argentyne per gallon,
   Betadine -- 38 ml Betadine per gallon
   \+ .38 g baking soda per gallon,
   or Wescodyne -- 24 ml Wescodyne per gallon
   \+ .38 g baking sola per gallon.

6. After 10 minutes transfer eggs to fifth tub and allow to rinse. After rinsing place eggs into incubators.

7. Disinfect transport water with chlorine at a concentration of 200 ppm or greater. Disinfect work area and utensils with 200 ppm or greater chlorine solution and rinse with clean water. Disinfect or dispose of shipping containers.

Materials Needed

5 tubs or troughs
- 1 for water hardening/holding received eggs
- 1 for formalin treatment
- 2 for rinsing eggs

1 for iodine disinfection
Cheesecloth or fine netting to suspend eggs in tubs
Clothespins or clips to hold netting
Argentyne, Betadine or Wescodyne
Baking soda (Sodium bicarbonate, $NaHCO_3$) if using Betadine or Wescodyne
Chlorine
Graduated cylinder, gram scale, sieve
Formalin

WARNINGS

Disinfection within 5 days of hatch may cause excessive mortality and/or premature hatching.

Do not change egg temperatures more than 5 degrees Fahrenheit during any stage of the disinfection. This can be done by increasing or decreasing the water temperature of each tub by 5 degree increments.

Pay particular attention not to mix contaminated water, hands or utensils with uncontaminated water or eggs when tempering and disinfecting eggs.

Avoid direct sunlight on the eggs if disinfecting outdoors.

ANNEX VIII

EMERGENCY ERADICATION PLAN

Whirling Disease caused by Myxobolus cerebralis, viral hemorrhagic septicemia (VHSV), infectious hematopoietic necrosis virus (IHNV), ceratomyxosis caused by a Ceratomyxa shasta, the myxosporidan parasite PKX the causative agent of proliferative kidney disease (PKD) and any other serious fish pathogen not known to occur or limited in their distribution are currently considered Emergency Diseases. Viral hemorrhagic septicemia is native to Europe and has only recently been isolated in North America west of the Continental Divide. Whirling disease, also native to Europe, is known to exist only in a few well defined areas within North America. Proliferative kidney disease has been a major problem in European fish farms and has recently appeared in North America west of the Continental Divide. Ceratomyxosis and IHNV also are serious diseases in North America west of the Continental Divide.

These incurable diseases may be spread by transporting infected fish or by transferring contaminated water or materials from contaminated areas. Control of these emergency diseases depends upon prevention and eradication. Therefore, outbreaks of diseases within the NASCO jurisdiction must be met with prompt containment and disinfection of the entire facility involved. The following eradication plan is presented to the member agencies to serve as a guide if an emergency disease outbreak should occur within their jurisdiction.

1. Organization

Each agency with jurisdiction should have a contingency plan well in place before an emergency disease outbreak occurs. It should develop legal authority if necessary in order to act quickly if an outbreak should occur in federal, state, provincial or private fish cultural facilities. It is hoped that voluntary compliance will be prompt regardless of the ownership of the affected facility, but the lead agency must have legal authority to act quickly. This authority also includes the necessity to obtain permits to use appropriate chemicals in the quarantine zone, establish emergency fishing restrictions in the area, etc. The lead agency must be able to establish adequate funding to ensure that adequate equipment, manpower, and supplies are available to conduct the eradication program. The lead agency should assist with indemnification for fish losses if appropriate.

The lead agency must develop a task force to conduct the emergency disease eradication project. An experienced fish health worker should be in overall charge of field operations. The manager of the affected facility and sufficient fishery personnel should assist the project leader for the duration of the project.

2. Quarantine

Whenever an outbreak of an emergency disease is suspected at any fish cultural facility within the agency's jurisdiction, an immediate quarantine of all fish at the facility involved will be imposed. If suspect fish have been transferred from the affected facility to other fish cultural facilities within the past year, similar quarantines will be issued to those receiving facilities until confirmatory inspection testing can be completed. The quarantine zone should apply to all waters within an area approximately determined by the lead agency surrounding the affected facility within that watershed and possibly further downstream if watershed conditions so indicate. All transfers of fish from the quarantine zone must be halted, including restriction of all fishing within the zone.

3. Investigation

The task force leader will obtain information on all shipments of fish, eggs, etc. from the suspect facility during the previous year. All recipients of suspect fish will be promptly notified.

Disease surveys will immediately be undertaken at the recipient station to confirm the presence or absence of the causative agent of the suspect emergency disease. Suspect samples will be sent to a second recognized fish health laboratory for confirmation. Surveys will be made of all populations of salmonids on the facility and within the quarantine zone. The size and location of survey sites will be determined on the basis of natural fish barriers, type of terrain, nature of the fish population, and characteristics of the disease outbreak itself. In addition, spotcheck surveys should be scheduled to include all susceptible fish populations located within the surrounding buffer zone, an area extending five to seven miles outside the quarantine zone.

4. Survey Procedures

A. Quarantine zone surveys:

All salmonid fish populations must be sampled at the earliest possible time. If other fish facilities are located within the quarantine zone, the task force leader in charge will call on each facility, explain the reason for his visit, the location of the infected facility, the nature of the disease, how it is spread, and advise the personnel concerning precautions necessary to prevent the spread of the disease and to whom they should report any suspicious disease signs among their own fish. The personnel at these facilities should be informed that reliable current information will be available by whatever means has been devised and be asked to refrain from spreading rumors. Strict sanitary measures should be followed before entering or leaving fish facilities in the quarantine or buffer zones.

During the period in which initial survey information is being collected from within the quarantine zone, every effort must be made to observe all fish, both domesticated and wild, for signs of any emergency disease and to collect representative samples from each population. Samples of fish displaying signs of the disease should be collected and documented as to precise location on the facility or stream, date collected, species and size of fish, name of the collector, and any abnormalities noted. Samples should not be frozen but should be packed on ice and processed in the laboratory as soon as possible. Subsamples should be taken and frozen or preserved in 10% formalin or both for documentation and future reference.

Strict sanitary measures must be observed by all personnel working within the quarantine zone as certain emergency diseases can be spread with the dirt on shoes, boots, tires, and by other means. Protective, disposable plastic boots should be worn when working on the facility grounds or along streams where the viable disease agents may exist. Vehicles should not be driven into fish rearing areas. Each piece of equipment or clothing that may have become contaminated must be thoroughly cleaned and disinfected before it leaves the facility.

NOTE: Suspicious disease signs among salmonids must be reported to the task force leader.

B. Buffer zone surveys:

Inspectors assigned to survey salmonid fish populations in the buffer zone must inspect all susceptible fish populations in the zone at least once. There is no alternative to laboratory examination of fish samples. Any salmonid showing suspicious signs, whether typical for the emergency disease or not, shall cause the inspector to conduct a close examination and to collect samples with full documentation.

5. Disease Eradication and Fish Disposal

Upon confirmation of the diagnosis of an emergency disease, immediate steps shall begin to assure the orderly decontamination of the facility. Except for properly disinfected fertilized eggs from populations affected only by whirling disease (Myxobolus cerebralis), all salmonid gametes, fertilized eggs and fish will be promptly destroyed and buried. A firm commitment to prompt action is essential to effective containment and eradication of emergency diseases.

To prevent possible reinfection of decontaminated areas, all stocks, except as noted above, must be destroyed. They should be killed with rotenone or HTH (chlorine) and buried in a deep pit or incinerated. The facility manager is in charge of stock disposal. He will secure the necessary equipment, materials, and permits to conduct the disposal operation. He will assign qualified personnel to operate digging equipment and instruct them in the preparation of the burial pit or arrange for transportation to an incinerator.

A fish disposal operation would consist of the following events:

A. Determination that a disposal operation is necessary (task force leader) and the method to be used;

B. Arrangement for the equipment and materials needed to carry out disposal (facility manager);

C. Preparation of the burial pit (facility manager);

D. Disposal of infected or exposed fish (facility manager).

These events should be carried out as soon as possible to limit any further spread of the disease, and further contamination of the facility, and any further discharge of infected facility effluent.

The site chosen for a burial pit should be within the grounds of the facility with easy access from rearing units but away from areas subject to flooding. The burial trench should be at least seven feet wide and not less than seven feet deep with the length determined by allowing fourteen square feet of floor space for each 1,000 pounds of fish to be buried. As the fish are placed in the trench, they should be covered with unslaked lime. Lime is to be applied at the rate of one barrel (850 pounds) for each 10,000 pounds of fish buried. This is to hasten decomposition and to discourage burrowing animals. The trench should be filled with earth without delay and the area should be included in the cleaning and disinfection procedures.

6. Cleaning and Disinfection

Cleaning and disinfection can start as soon as disposal is completed. The members of the task force involved in work in infected areas must be supplied with rubberized rain gear including boots, coat, hat and gloves. These outer garments will be removed and left in an appropriate location at the end of each day's work. These items should be thoroughly disinfected during the final phase of disinfection.

In addition to the chemicals required, the equipment listed below would be helpful in the disinfection of facilities:

1 high pressure spray unit	2 wire brushes
4 50-ft. lengths of hose for sprayer	2 heavy brooms
6 pairs of rubber boots	5 five-gallon pails
6 sets of rain gear, complete	3 pairs of safety goggles
6 pairs of rubber gloves	6 respirators
1 1/2-ton pickup truck	5 300-gallon stock tanks

All fish rearing facilities should be brushed clean of moss, algae, dirt, and organic wastes. Rearing tanks, incubators, troughs, outdoor raceways, and water supply headboxes and tail-race should all be thoroughly scrubbed. Consideration should be given to the treatment of the effluent from these cleaning operations to minimize the contamination problem. Earthen ponds should be drained and the entire bank area cleared of vegetation and debris. Earthen ponds should not be dried and should not be entered except under close control.

Disinfection can begin as soon as the facilities are cleaned and readied. All buildings and the equipment within them should be disinfected with chlorine, Amphyl, or other appropriate disinfectants.

Streams, water supplies, pipeline systems and the facility effluent should be chlorinated. These are difficult to disinfect and success largely depends upon the length of time the disease organism is exposed to the disinfectant. In no case should chlorine be used at less than 200 parts per million for a period of less than one hour.

Scrubbed, hard-surface rearing units can be effectively disinfected by spraying them with a 1,000 ppm solution of Roccal or Hyamine 3500. There is a considerable residual effect with these compounds and all units treated with them should be thoroughly rinsed before use. Chlorine at 10,000 ppm or more may also be sprayed on hard surfaces where residual activity is not desired.

Earthen ponds, canals, and the like present special problems for disinfection. Several treatments with unslaked lime (CaO) at the rate of two tons per acre may be required. Unslaked lime is the compound of choice and it should be applied to freshly drained ponds. The ponds should stand for a month or more. At that time, the muck should be removed and buried in a pit. The ponds should then be refilled and tested with fingerlings of the species and age most susceptible to the emergency disease in live boxes for 120 days. The progress of any possible reinfection should be regularly monitored for at least 60 days through laboratory examination of representative fish. If the ponds are still infective, terminate the bio-assay and treat the ponds again. Consideration should be given to the complete renovation of contaminated earthen ponds.

7. Post Disinfection Surveys

After the facility has been cleaned and disinfected, a 30-day waiting period should be observed before actual live fish tests start. During this "cooling off" period, all rearing facilities should remain dry and, if possible, exposed to sunlight. The number of test fish should be determined by the size of the facility to be tested. Each rearing unit should be tested by placing a minimum of 100 fingerlings of the species and age most susceptible to the disease in question, in a live box near the outlet of each rearing unit. The water in the rearing units should be held at the normal operational level. Samples of fish from various locations will be collected after 60 days exposure for laboratory examination. All fish will be sacrificed after 120 days exposure for laboratory examinations. The test fish should be regularly fed and cared for during the exposure period.

After the completion of a negative 120-day test period, all concrete rearing units which are supplied with uninfected water may be restocked with disease-free fish, or, preferably, eggs. These fish should be inspected for the causative agent resulting in the eradication at intervals of 90 days or less for at least one year. Earthen ponds, ditches, and streams should be retested a second time. At the completion of two negative tests, these units may be restocked and the quarantine released. In instances where earthen pond and cement raceways adjoin, no production program will be initiated until the earthen ponds are determined to be free of the organism, as described above.

ANNEX IX

QUARANTINE FACILITIES

A quarantine facility must be inspected and accepted by fish health personnel from the agency granting the importation permit but should meet the following requirements:

1. The incubation/rearing facility must be physically separate from other fish cultural activities, must be completely enclosed and secure to prevent entry of birds, animals and unauthorized personnel;

2. The water supply must be known to be free of all listed fish pathogens;

3. Access to the facility should be limited to essential personnel. Foot baths with PVP iodine at 250 mg/l or other appropriate disinfectant must be properly used and maintained. The facility must be fully supplied with essential equipment so that it will not be necessary to remove any equipment from the facility to other locations. All equipment being removed must be thoroughly disinfected;

4. All of the effluent from the quarantine facility must be treated with chlorine at a concentration that will never be less than 5.0 mg/l with at least a 10-minute retention time before being discharged. The chlorinated effluent must be neutralized before discharge into surface waters.

P A R T I I I

PROTOCOLS FOR MAINTENANCE OF GENETIC DIVERSITY IN ATLANTIC SALMON

by

Genetics Subgroup of
NAC/NASCO Scientific Working Group on
Salmonid Introductions and Transfers

Members:

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1 INTRODUCTION

Atlantic salmon populations can respond to long-term environmental change with genetic adaptation, provided they possess sufficient genetic variation. If biotic and/or abiotic environmental factors change rapidly, due to anthropogenic effects for example, discrete Atlantic salmon stocks may not be able to respond genetically to these new conditions, resulting in loss of fitness and possibly extinction.

It is now generally accepted that each river that can support Atlantic salmon may be inhabited by one or more genetically distinct forms. Over time, salmon have become genetically adapted to their native river habitats. The genetic variability within such discrete stocks provides the potential for adaptation to local environmental change. If genetic variability is diminished, Atlantic salmon stocks may not be able to respond to environmental uncertainties and may not be able to sustain themselves. It is therefore of paramount importance for the effective management of the Atlantic salmon fishery to develop protocols which will ensure that genetic variation is not reduced significantly, both within and among North American Atlantic salmon stocks.

For the purposes of developing protocols for maintaining Atlantic salmon genetic variation, it is useful to define the following species subdivisions:

(a) Population - A group of individuals occupying the same waters at least during part of their life cycle;

(b) Stock - A group of self-sustaining individuals that share the same environment and gene pool;

(c) Strain - A group of cultured individuals of common ancestry.

The maintenance and sustainability of genetic variation in wild Atlantic salmon can be affected by human activities. Anthropogenic impacts can result in changes of gene frequencies, the addition of non-native genes, the loss of native genes and/or gene combinations, and the loss of natural genetic variation. Specifically, management activities involving introductions, transfers, fish culture (especially cage culture), and selective harvest can negatively alter natural genetic variation. The emphasis in the development of protocols will be on the impacts of introductions, transfers, and culture rather than selective harvest. The protocols which follow are predicated on techniques known to prevent loss of original stock genetic variation.

2 PROTOCOLS

2.1 Inter-continental transfers

The transfer of Atlantic salmon between continents and, in particular, from any continent to North America, should be prohibited because of the change that such transfers would impose on the genetic integrity of North American stocks. Support for this recommendation includes evidence that large genetic differences exist between North American and European stocks, and that transplantations are more successful if stocks of local origin are used rather than distant sources. Furthermore, imported salmon may interbreed or displace North American stocks, resulting in the loss or alteration of native genetic variability essential for long-term persistence and adaptation under North American environmental conditions.

2.2 Intra-continental transfers

2.2.1 Introduction and re-establishment

These activities pertain to development of salmon fisheries in rivers not presently inhabited by wild salmon. In one case, the river may have suitable salmon nursery habitat but be barred from use by natural obstacles such as impassable falls. Other rivers may have been historically inhabited by wild salmon, but have lost their wild salmon due to natural or man-made changes in the river. Protocols for re-establishing salmon in such rivers are as follows:

(a) Local stocks having matched characteristics such as seasonal patterns of smolt migration and adult returns should be used as donors. The donor stock should also have marine migratory patterns that match the pattern required by the recipient stream and have originated from in-stream habitat that is similar to that of the recipient stream;

(b) Early life stages (i.e. eggs, fry, or parr) are preferred over hatchery-reared smolts, because these stages allow some natural selection and survival of individuals best suited to the new environment. Early life stage plantings also eliminate possible negative hatchery-rearing effects, such as long-term acclimatization to hatchery conditions and behavioral alterations. Releases of hatchery-reared fish should be made in cognizance of limitations in juvenile rearing habitat and of interference with other life stages planted earlier;

(c) Single pair matings and efforts to maximize the effective number of parents (N_e) should be adhered to during hatchery production of juveniles for release. See mating protocols in Section 2.2.4.

2.2.2 Rehabilitation and enhancement

These activities pertain to development in rivers presently inhabited by remnant stocks of wild salmon. Rehabilitation and enhancement activities are a potential threat to the integrity of wild stocks, through possible introduction of genetic material that is different from, and which might alter, the genetic makeup of existing wild stocks. Such introductions could result in reduction of stock fitness. Also, the introduced fish may simply displace the native fish, either because they vastly outnumber them or because they have a temporary competitive advantage. In general, these protocols for introductions are directed towards minimizing genetic impact on wild stocks, with emphasis on rebuilding or increasing numbers in existing wild stocks.

(a) The most effective and lowest risk rehabilitation and enhancement measure is to improve degraded habitat and to maintain a sufficient number of spawners to allow the local stock to rebuild itself. Habitat protection and improvement, together with regulation of exploitation are the time-tested methods for stock enhancement.

(b) Native, residual stocks should be used to rehabilitate or enhance stocks in a particular tributary or system. Should existing stocks be too few, a donor stock from another tributary or nearby river, and with life history and genetic characteristics similar to those of the recipient stock, should be used. A hybrid of the native and a neighbouring stock is preferred over use of the neighbouring stock alone, but less desirable than use of the native stock exclusively.

(c) Hatchery-reared smolts are the preferred early life stage for planting. These smolts do not compete with younger wild juveniles and would, therefore, not reduce production of wild fish. Also, smolts would contribute more potential spawners sooner than earlier life stages of stocked juveniles.

2.2.3 Cage culture - marine enclosure

The potential negative impact of aquaculture escapees on wild stocks is of great concern. Although there are data for other salmonids showing the negative impact of non-indigenous stocks on native stocks, no such data, pro or con, exist for Atlantic salmon. However, captive salmon do escape from cages and/or enclosures. For example, it has been estimated that in some Norwegian rivers, over half of the adult salmon are of farmed origin. We have assumed that a negative impact is probable, particularly in light of recent experiences in Norway, and that the genetic resources of all wild stocks are equally valuable. The following protocols are designed to minimize the risk to wild stocks. Present economic value was not considered.

(a) Prevention of escapees is considered to be the most important objective. The operator must ensure that the containment facilities are in good repair and that staff are adequately trained in the handling of fish.

(b) Where available, the use of domestic strains derived from local stocks should be encouraged. Where not available, they should be developed from an appropriate nearby stock, rather than importing distant strains.

(c) Commercial sea ranching can be considered another phase of culture where juvenile salmon are released to be harvested later as one sea-winter or older fish. Such releases should be made in areas where the resulting production would not adversely affect wild salmon production by competition for habitat or potential mates. Sea ranching should only be practised if sea ranched fish home precisely to release sites where they have no impact on native fish communities.

2.2.4 Hatchery management

Protocols for hatchery management may pertain to breeding, facility design and intentional and unintentional selection during wild sampling or hatchery-rearing.

(a) Cultured brood stocks held in captivity for several generations and used for aquaculture (i.e., cage culture) should not be used for wild fish management. For public fisheries support programs involving introductions, re-establishment, rehabilitation, or enhancement, single use of progeny (i.e., no captive brood stocks) derived from annual egg collections from wild fish is the preferred strategy.

Cultured (domesticated) stocks may become adapted to controlled environments which differ substantially from wild habitat. It has been reported repeatedly that domesticated stocks have lowered fitness in the wild. Such stocks may interbreed with wild stocks and have a negative genetic impact on them. If they substantially outnumber residual wild stocks, they may displace them by competition for space. Ultimately, they could replace genetically diverse wild stocks that are adapted to local habitats with genetically more uniform stocks that are poorly adapted to the wild.

(b) Stocks for wild fish management should be derived from a wide cross-section of phenotypes, spanning all age types and the entire run of the donor population.

Selecting only part of the phenotypic distribution of the wild stocks can result in inadvertent directional selection or truncation selection. It has been demonstrated that characters, such as spawning time and age of maturity, are under genetic control and can be altered by selection. The resulting altered genotype will probably be less well adapted to the wild habitat. Also, selection will result in a general loss of genetic variability which has been associated with loss of fitness.

(c) Selection of the stock during hatchery rearing should be avoided.

There is a tendency to select fish in the hatchery that are better adapted to hatchery conditions, i.e. fish that are easily domesticated. Such selection can result in fish that are genetically better adapted to the controlled hatchery environment than the wild environment for which they are intended.

(d) Single paired matings and an effective number of parents (N_e) not less than 100 should be used to derive each year-class. Should the number of one sex be fewer than 50, the number of spawners of the other sex should be increased to achieve a minimum N_e of 100. $Ne = \frac{4N\_N\_}{N\_+N\_}$

Milt from individual males should be used separately.

Using a smaller effective number of parents results in significant inbreeding which will result in loss of fitness. Mixing eggs and sperm of several individuals can result in fewer individuals contributing genetically to the stock and, hence, reducing the effective number of individuals.

2.3 Fishery harvest

Fisheries potentially reduce genetic diversity, which can lead to loss in fitness. Accordingly, fisheries should be managed to ensure equal vulnerability of all genotypes of a particular stock.

Fishery harvests should be stratified with respect to fish size, age, sex, and seasonal pattern of availability, to maintain natural variation of all phenotypes. Where natural variation has been altered by previous exposure to fisheries, such as the Greenland fishery which harvests older, maturing salmon, selective fishing might be desirable in the home river to re-establish natural variation within spawning stocks. Expansion of gillnet fisheries should be discouraged because of their selectivity for fish size. The use of gill nets within the river, where exploitation of individual stocks is potentially greatest, is of major concern.

3 RESEARCH REQUIREMENTS

3.1 Stock identification and inventory

(a) An inventory of wild stocks and their habitats and of available domestic strains should be developed. The approach should be multivariate and include morphometric data, life history information, DNA profiles, electrophoretic information, etc. This survey should receive the highest priority and be initiated before aquaculture escapees have the opportunity to impact wild stocks.

(b) An inventory of life history differences among wild stocks and the degree of genetic control of such character differences should be made. Such information would provide a better information base for choosing appropriate donor stocks. In conjunction with the stock data collection, a habitat inventory should also be conducted.

3.2 Assessment of enhancement and rehabilitation practices

(a) Genetic changes should be monitored over time, following introduction of a non-native stock where there is a potential for interbreeding with the native stock. Research should include analyses of morphometric data, study of life history characteristics, electrophoretic analysis, and DNA characterization of recipient, donor, and possible hybrid stocks, to document any significant genetic changes and offer a basis for future management strategy.

(b) The use of gene banking by cryopreservation and androgenetic means should be considered if and when a stock is reduced to less than 100 individuals.

(c) The consequences of temporal genetic changes in stocks transferred to refugia should be monitored and assessed, in relation to the later use of these stocks.

3.3 Aquaculture practices and effects

(a) The extent of straying of hatchery-origin potential spawners and their genetic effects on wild stocks should be assessed.

(b) Biotic and abiotic techniques of sterilization of cultured stocks, to prevent introgression of cultured and wild stocks, should be assessed.

(c) Both the rate at which salmon escape from cage culture marine enclosures and the extent of straying after escape are unknown. Basic areas of research that need to be addressed include:

- The extent of migration of escapees into salmon rivers;
- Competition between escapees and native salmon;
- Natural reproduction, growth, and survival of escapees relative to wild salmon;
- The interaction between escapee or hybrid progeny and native progeny.

This information is required for modelling exercises aimed at predicting future risks of escapees to wild salmon.

(d) Sterilization techniques hold promise for aquaculture stocks and for reducing the genetic risks they pose to wild stocks. Research is necessary to develop sterile strains that grow as well as and are of comparable quality to fertile strains.

(e) The development of specific strategies to forestall escapees from culture operations and the means to contend with escapee recapture should be assessed.

(f) Fish culture practices which prevent inbreeding and selection:

- Studies of possible selection effects of sperm cryopreservation in gene banks;
- Study possible effects of the use of precocious parr for breeding purposes on the genetic integrity of stocks;
- Develop genetic monitoring programs with techniques for identifying changes in genetic variation.

3.4 Fishery harvest effects

An assessment of gear selectivity is required to determine its effects on genetic variability within and among stocks under intensive harvest.

4 CONCLUDING REMARKS

It is acknowledged that in the interest of preventing damage to the genetic integrity of North American Atlantic salmon, the Genetics Subgroup chose to take a very conservative approach. Each of the protocols, although not always supported by Atlantic salmon research, is known to sustain genetic variation in other species. Further research involving Atlantic salmon is required to fully justify the protocols.

The Subgroup realizes that, along with sustaining genetic diversity, habitat preservation is equally important. Fishery resource agencies should consider the use of gene banks for stocks of Atlantic salmon already highly depleted as a result of overharvest and/or habitat loss.

PART IV

PROTOCOLS TO REDUCE RISK OF ECOLOGICAL EFFECTS OF INTRODUCTIONS AND TRANSFERS OF FISHES ON ATLANTIC SALMON

by

Ecological Subgroup of
NAC/NASCO Scientific Working Group on
Salmonid Introductions and Transfers

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1 INTRODUCTION

Stock management and commercial use of Atlantic salmon resources often provide apparent justification to introduce or transfer stocks of the species. In addition, management of freshwater species may involve recommendations for introductions or transfers of other fish species into or close to Atlantic salmon habitat. Agencies with responsibilities for the native fishes in a geographic area usually group the outstanding concerns under three topics: fish disease, genetic impacts, and ecological impacts. Man has the technology and knowledge to reduce risks related to fish disease movements, but knowledge about most genetic impacts is based on scientific reasoning rather than extensive empirical information. Knowledge about the ecological concerns requires extensive background information which is not yet available in adequate form. Pre-assessing the ecological impacts of a proposed introduction or transfer is the most difficult of the three mentioned major aspects. This document identifies potential intra- and inter-specific ecological impacts on Atlantic salmon that should be considered before introductions or transfers are made.

2 IMPACTS OF INTRODUCTIONS AND TRANSFERS

2.1 Intra-specific effects

2.1.1 Predation

Intra-specific predation by introductions or transfers would most likely occur at the younger and smaller stages. Dislodged eggs are known to be eaten by parr, but there is no evidence that eggs normally buried in redds, or artificially planted in the substrate, are eaten by parr (Jones 1959). Introduced alevins or fry are disoriented and stressed after travel and can be heavily preyed on by resident parr soon after stocking (MacCrimmon 1954). Stunned or displaced fry in electrofishing operations may be eaten. Also, salmon fry have been found in stomachs of parr from lakes (unpublished data, R. J. Gibson). However, resident fry in preferred habitats are not normally eaten by wild parr (Gibson et al. 1984; Thonney and Gibson, 1989), so that introduced parr are unlikely to prey on resident fry. If densities of fry were increased by stocking, there could be increased downstream movements of fry, with their occupation of atypical habitat, possibly increasing their vulnerability to predation. It is not known if emigration would be more by the introduced rather than resident fry. Resident fish are usually less likely to be displaced, but Symons (1969) showed that stocked hatchery salmon fry dispersed little. If the introduced fry were larger than the residents, they would have a competitive advantage and possibly displace the resident fish, which could then be susceptible to predation.

2.1.2 Competition

Intra-specific competition is most severe within size classes since there is some habitat segregation between year or size classes. Also severest agonistic behavior is between fish of equal status and size (Symons 1968; Chapman and Bjornn 1969), and dominance in territorial behavior is based to a large extent on size (Abbot et al. 1985; Chandler and Bjornn 1988; Gibson 1988).

Generally introduced fish are at a disadvantage to resident fish (Miller 1958; Mason and Chapman 1965; Payne 1975). However, if densities were already high, introductions of large-sized parr possibly could cause displacement of smaller resident fish. Alternatively, since growth of young salmon can be density dependent (Gibson and Dickson 1984) higher densities due to introduced fish could cause reduced growth and related increase in mortality of resident fish. Intra-specific competition between size or year-classes has been suggested by Elson (1975) and Egglishaw and Shackley (1985), so that introduction of parr could possibly negatively affect survival of 0+ in some systems. However, intra-specific competition between year-classes is not apparent in some rivers (Côté and Pomerleau 1985), depending probably on the diversity of habitat and species composition. Deliberate introductions of adult fish are less likely, but escapes from aquaculture operations occur. Competition for redd sites and overcutting of redds of the indigenous stock are then possible.

2.2 Inter-specific effects

2.2.1 Predation

Salmonids generally are opportunistic feeders and under certain conditions are piscivorous, so could have negative effects on young Atlantic salmon. For example, young coho salmon are known to eat salmonid fry (Hunter 1959; Roos 1960; Ruggerone and Rogers 1992), and brown trout will prey on smaller salmonids (Alexander 1979). Large brown trout (>35 to 40 cm) are primarily piscivorous (Clapp et al. 1990) and in Europe have been shown to be important predators of salmon smolts (Piggins 1958). Brook trout normally do not prey on young salmon in rivers, but large brook trout in lakes can be piscivorous (Power 1980). Large rainbow trout can prey on small fish (Johannes and Larkin 1961; Northcote 1973), and lake trout and large Arctic charr are piscivorous (Scott and Crossman 1973; Matuszek et al. 1990). Introductions of other salmonids must therefore take into account predatory effects, including by large trout in lakes, which would have serious consequences in areas where young salmon utilize or migrate through lakes, and on migrating salmon smolt in estuaries, by predatory species such as large anadromous brown and rainbow trout. An introduced salmonid might temporarily increase the total density of salmonids, thereby attracting more or other predators, including man, which possibly could increase the proportional mortality of salmon. For example, a heavy run of an exotic salmonid, such as coho, would attract anglers trolling in the estuary, who would probably catch Atlantic salmon as a by-catch.

Of more serious consequence would be introductions of highly predacious non-salmonid species, such as pike and pickerel (Esox sp.), walleye and sauger (Stizostedion sp.), or bass (Micropterus sp.). Judging by the virtual absence of salmon parr in lakes where these species exist, lake rearing of young salmon would probably be eliminated, and rivers with slow stretches, which may be productive of young salmon, as in Newfoundland and parts of Quebec and Labrador, would have rearing capacity for juvenile salmon considerably reduced (Gibson and Côté 1982). Also, piscivorous species such as pike (Esox lucius) and burbot (Lota lota) would be major predators of migrating smolt (Bakshtansky et al. 1982; Larsson 1985). Top predators have important effects in structuring fish communities, so that introductions of predators could eliminate species, or cause changes in the fish community and ecosystem, causing unknown effects on salmonids (Pimm and Hyman 1987; Evans et al. 1987; Witte et al. 1992).

2.2.2 Competition

There are two forms of competition: exploitation and interference (Brian 1956). One method may be responsible for displacement of a species or both mechanisms may be used concurrently. Also competition may act only at certain life history stages, or the direction may change at certain stages or in different habitats (Hartman 1965; Hayes 1989; Rose 1986). For example, salmon parr can displace larger-sized brook trout from fast water areas by exploitation when the available food becomes scarce (Gibson 1973), whereas brook trout in a pool type of habitat negatively affect the growth rate of large salmon parr which can also occupy such habitat (Gibson and Dickson 1984). Interference is regarded as the ability of a species to damage another either directly by attacking its individuals or indirectly by harming its resources or blocking its access to them; it does not necessarily use the same resources itself. For example, in flowing water young steelhead trout can displace similar-sized Atlantic salmon parr by aggression (Gibson 1981). Similarly, salmon parr are more aggressive than small brook trout in flowing water and can displace yearling trout by this mechanism (Gibson 1973). Other examples of interference might be: the overcutting of redds by another salmonid, with loss of eggs or alevins; competition by the eggs for oxygen; competition with the food of a prey species, indirectly reducing the food supply of another salmonid; the presence of another salmonid may induce behavioural or density-related stress factors causing reduced feeding or growth, with secondary negative effects, such as increased vulnerability to pathogens, parasites and predation, and delayed maturity of male parr.

Atlantic salmon and brook trout are naturally sympatric in eastern North America, and although their niches overlap, they have evolved to be ecologically compatible (Gibson et al. 1993) as have brown trout and Atlantic salmon in Europe (Heggenes and Saltveit 1990). However, even with native species it may be inadvisable to introduce or transfer forms which may not have evolved sympatrically, such as large piscivorous varieties of brown and brook trout (Ferguson 1986). Greater dangers probably are from introductions of species which are not naturally sympatric, but have evolved allopatrically and occupy similar niches as young salmon in other geographical locations (Gibson 1988).

A new species may completely displace a previously resident species, it may occupy an unfilled niche, or it may partition a niche with a pre-existing species. An invader by some specialization may be able to compete successfully for the marginal parts of a niche. It is probable that invasion is most likely when one or more species happen to be fluctuating and are under-represented at a given moment (Elton 1958; Hutchinson 1959).

However, an alternate hypothesis is that invasion of a species can occur when environmental changes allow the species to adapt (Hengeveld 1988). Nevertheless, successful introductions have occurred in stable habitats with complex species flocks, such as, in the African Great Lakes (Ribbink 1987).

In general, successful colonization is likely where a sufficiently plastic new species occupies a niche either temporarily or permanently having little overlap of the niches of resident species, so that low diversity is more conducive to the success of an invader than high diversity (Christie et al. 1972; Griffith 1988). The latter situation of low diversity is commonly the situation of northern salmon rivers, where the glacial history and isolation have restricted colonization, as in Newfoundland. Probably the most damaging impacts would be by non-salmonid competitors, which could more efficiently use niches which young salmon may be able to exploit in the absence of severe inter-specific competition. Riffle dwellers such as cottids, some suckers (Catostomidae) and some darters (Percidae) may compete with young salmon. The most serious damage to salmonid production by introductions has been from non-salmonids, sometimes officially, to provide angling, or as 'forage fish', but also unofficially by release of bait fish, or other reasons. For example, introduction of redshine shiner, Richardsonius balteatus as a 'forage fish' resulted in decrease in growth and survival of small rainbow trout (Oncorhynchus mykiss), by competition, although large trout were able to prey on the minnow (Johannes and Larkin 1961). Similarly, brook trout biomass in lakes is reduced by creek chub (Semotilus atromaculatus) and white sucker (Catostomus commersoni) (Magnan 1988). Johnson (1964) found that 'forage fish' reduced biomass of brook trout in farm ponds by more than one half. It is likely lacustrine juvenile salmon would similarly be affected. Other species such as perch (Perca sp.), sunfish (Centrarchidae), white perch and bass (Morone sp.), smelt (Osmeridae), are likely to be severe competitors of salmonids in lentic waters (e.g. Fraser 1978) and especially of salmon parr, since they are better adapted to these habitats than young salmon. In lotic conditions the niche of Atlantic salmon is generally restricted to fast shallow waters in the presence of some competitors, but parr can also occupy flats, pools and lakes when these competitors are absent (Gibson and Myers 1986; Gibson et al. 1993). Therefore in Newfoundland and parts of Quebec and Labrador, where lentic waters provide a major part of Atlantic salmon production, such introductions would have serious consequences. For example, Ireland, like Newfoundland, due to its glacial history, had a depauperate fish fauna, colonized only by euryhaline species. However, in addition to the salmonids there are now 13 other freshwater species, of which eleven were introduced (Went 1957; Fitzmaurice 1986; Welcomme 1991). Although 'coarse' fishing has been provided, in some areas these introductions have become pests, competing or preying on the indigenous salmonids (Fahy 1989).

2.2.3 Other effects

Moyle et al. (1986) list six mechanisms that allow introduced species to succeed by displacing native fishes: competition; predation; inhibition of reproduction; environmental modification; transfer of new parasites or diseases; hybridization. The first two mechanisms have been discussed above, as these are related to possible ecological consequences of introductions and transfers, but other mechanism are possible. The latter two mechanisms are covered in other protocols.

3 SPECIFIC CONSIDERATIONS FOR INTRODUCTIONS AND TRANSFERS

3.1 Ecological background on proposed new donor stocks or species

Since interactions between species may occur at any life-history stage, with consequences for the species as a whole, thorough envirograms[1] (Fig. 1) for each species should be constructed so that hypotheses related to possible interactions can be formed. Ontogenetic shifts in feeding behavior and habitat distribution and the possible interactions with resident species need to be carefully considered. If conditions are unfavorable for the donor stock or species at any stage, such as photoperiod induced maturity at suitable temperatures, the introduction may fail. For example, in the case of anadromous salmonids, for redd construction, environmental conditions must be considered for holding areas for spawners, type of substrate, and water velocity, depth, water chemistry, and climate. Environmental conditions must be suitable for incubation, timing of emergence and the rearing of the fry and parr. Smolts must emigrate at the correct time in order to enter the sea over the short period when temperatures are suitable for the physiological changes that must occur for entry into sea water, suitable food is present, and predators are few. Their migration to a foreign marine community may be difficult, since mature communities are more resistant to invasion than more simple communities (Pimm and Hyman 1987). The adults must have a suitable migratory 'compass' to enable them to find feeding grounds and return to home rivers, and must arrive when water temperatures and flow conditions are suitable for migration upriver. Most attempted introductions of Pacific salmon have failed (Ricker and Loftus 1968; Harache 1988), although other more plastic salmonids, such as brown trout and rainbow trout, have been successfully introduced in many cases (MacCrimmon and Marshall 1968; MacCrimmon 1971). Straying rates vary between stocks and species, but straying would probably be inevitable with any introduction. The probable geographic range that may be invaded, which would be limited mainly by climate and temperature tolerance of the species, should therefore also be considered.

3.2 Ecological characterization of indigenous stocks

Similarly, the indigenous stock should also be characterized with an envirogram for complete life history. This would include spawning and redd construction, incubation, niches of the fry and parr at different times of year, migratory pattern, habitat and feeding of the smolts, distribution and feeding of the adults, and migratory routes and behavior. Possible interactions from introductions at a vulnerable life history stage would then be more apparent, facilitating the necessary studies.

3.3 General ecological considerations

Although the ecologies of important commercial and sports fishes are known in general, complete data for predicting interactions are not available. Freshwater fishes, at least in most coldwater environments, are in general plastic in both habitat and

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[1] Envirogram = a graphic representation of environmental modifiers, including both proximate and distal causes (Andrewartha and Birch 1984).

feeding requirements (Larkin 1956), and a species may have many ecologically distinct forms (Behnke 1979), so that introduced fish may show 'ecological release' and adapt differently to the new environment as compared to their original habitat. Tentative predictions at present are based on empirical data and with no species is it possible to predict the effects of introduction on Atlantic salmon with certainty, since the necessary rigorous experiments involving both laboratory and field work are lacking (Fausch 1988; Gibson 1988; Chiasson et al. 1990). It is therefore recommended that well-planned laboratory and field experiments be conducted on species interactions before release, and to cover all life history stages. In the interim no non-indigenous fish species should be introduced into a system with viable stocks of Atlantic salmon. Similarly introductions of 'forage fish' for brook trout or ouananiche into waters with anadromous salmon should not be considered, including parts of the drainage basin from which invasion to salmon habitat could occur.

Although there may be regulations to the contrary, non-native species frequently are introduced (Courtenay and Stauffer 1984). Some areas, such as Newfoundland and Labrador, and parts of Quebec, have been free of damaging introductions. However, as human populations and communications increase, it is inevitable that such introductions will appear. In order to speed decision making, before such species are introduced over adjacent watersheds, there should be a policy on hand for speedy and radical action, such as poisoning out a system to eliminate all fish species where an introduced species has appeared. It is likely the species would be stenohaline and naturally confined to the system until it could be eradicated. With unique stocks of salmon, some plan would have to be in place to treat a river after the smolt run and while adults were at sea, or to harbor sufficient numbers of the stock for re-introduction after treatment.

Where introductions and transfers are likely to result in long-term sociological or economic benefits, and the most recent data indicate unlikely negative effects on salmon, these introductions could be supported, since too restrictive regulations will result in their being ignored by local authorities. For example, rainbow trout are economically and sociologically beneficial in the Great Lakes, Gulf of St. Lawrence, many European systems, and elsewhere, and so far have not been shown to colonize any major salmon river, or to have negative impacts on Atlantic salmon, despite extensive opportunities to do so. However, if over-exploitation, enrichment, or some other disturbance changed the ecosystem, successful colonization could occur. Theoretical and empirical data suggest that introductions are most likely to be successful where the ecosystem has been perturbed (Herbold and Moyle, 1986; Pimm and Hyman 1987). This appears to be the case with successful invasion of former salmon rivers by rainbow trout in Lake Ontario (Christie 1972) and by brown trout in Newfoundland (Gibson and Cunjak 1986). Stocking into rivers with salmon populations should be discouraged unless thorough evaluations indicate that there will be no interactions with Atlantic salmon. Marine cage culture of rainbow trout could be permitted where rainbow trout presently exist and no impact on salmon has been observed. Expansion of cage culture to other areas would require an evaluation of the potential for adverse effects on Atlantic salmon. Similarly, cage rearing and sea ranching of Arctic charr would be possible in cold marine environments, and strays into salmon rivers are unlikely to have negative impacts on the salmon resource. However, this latter consideration is at present the subject of a research project by DFO in the Gulf Region.

Enhancement activities should not be hindered where there are likely to be benefits. For example, where salmon stocks have been lost due to physical degradation of habitat, previous pollution, acid rain, or artificial obstructions, re-introduction of salmon would be beneficial if the river were reclaimed to once more sustain anadromous salmon, local stocks being most likely to succeed. Similarly, local stocks of salmon should be allowed to be transferred above natural obstructions, to extend their range and production, taking into account effects on other species upstream, such as displacement or reduction of a valuable resource by competition or hybridization, as might occur with important brook trout or ouananiche fisheries, or the introduction of less desirable species upstream by allowing easier passage.

4 PROTOCOL FOR INTRODUCTIONS AND TRANSFERS

In general for North America there has been no introduction of a fish species into pristine waters which has provided sociological or economic benefit that some indigenous species did not already provide. Most introductions have been failures and, for those that succeeded, displacements, loss of fitness, or extinction of local species or races resulted. However, in perturbed ecosystems, caused by over-fishing or changes in habitat, introductions have successfully replaced or supplemented species of economic importance as, for example, the introductions of Pacific and European salmonids in the Great Lakes.

A new development is in aquaculture, where non-native species raised in cages may provide better economic returns than native species. Escapes from these ventures are inevitable.

It is suggested therefore that introductions and transfers be considered under three categories: (1) pristine ecosystems; (2) disturbed systems, where the habitat or water quality has been changed, but where the indigenous fish community remains intact; (3) changed ecosystems, where the fish community has been destabilized and exotic species may be present.

- Under (1) for example might be placed most systems in Newfoundland, Labrador, and Quebec, with many in the Maritime provinces, such as the Restigouche River and many areas of the Miramichi River.

- Under (2) would be many rivers in the Maritime provinces and in Maine, and some in Newfoundland and Quebec.

- Under (3) would be some rivers in the Maritime provinces and many rivers of the Great Lakes, St. Lawrence River, and on the eastern seaboard of the USA.

Decisions should however be made at the river or tributary level rather than solely by region.

In categories (1) and (2) it is recommended that no introductions of non-indigenous species be considered since local fish communities remain intact and the effects of introductions are unpredictable and may change the unique characteristics of a system. Also in category (1) no transfers should be considered since in most areas the characteristics and value of local sub-species and races are unknown. Some local races may have attributes such as fast growth, large size, adaptations to climate or predators, etc., with subsequent loss of fitness with interbreeding of other stocks or hatchery fish, a recognized consequence in studies with other salmonids (Chandler and Bjornn 1988). In category (2) transfers of indigenous species can be considered, but only under the constraints of the genetic and health protocols. In this area salmon might be established or re-established to a river by using a stock from a nearby river with habitats similar to the system into which salmon would be transferred. Rehabilitation by regulation of the fisheries is the preferred option; alternatively, the use of resident stocks is preferred over transfers of non-indigenous stocks. Extensions of range within watersheds in categories (1) and (2) may take place for enhancement activities using transfers of downstream populations and taking into account possible negative effects on the fish communities upstream (e.g. inter-breeding with ouananiche, competition with brook trout, allowing fish passage for non-salmonids).

Areas in category (3) may have long lost their Atlantic salmon stocks and no local races may be available. Restoration of the fishery may only be possible with supplementation by hatchery fish. Such areas would be rivers draining into Lake Ontario, Merrimack River, and the Connecticut River. Salmon stocks from as near as possible should be used. Introductions of non-native salmonids may be considered, but with careful study of the following questions for the probable benefits:

(a) Is the introduction likely to have sociological and economical benefits?

(b) Would the introduction be likely to destabilize the existing fish community (e.g. a highly predacious fish)?

(c) Will the proposed introduction add to or merely substitute for an existing fishery? If a substitution, would it be more valuable?

(d) Would the proposed introduction be likely to be self-sustaining by having breeding populations, or would the fishery be maintained by hatchery stockings?

(e) If the introductions were likely to succeed, would this interfere with self-sustaining Atlantic salmon stocks in nearby rivers, or conflict with potential rehabilitation programs?

Under the latter consideration, (e), an envirogram (dendrogram of the ecological web) (Fig. 1) should be constructed for all life-history stages. If the species would not have negative effects, as for example if habitats at any stage did not overlap, the introduction could proceed, but under the constraints of the fish health protocols. If there were lack of information, thorough research projects to fill the data gaps should be undertaken. The above considerations would apply also to planned introductions of non-salmonids. It should be borne in mind that the recommendations for category (3) above reflect the present reality of fisheries management in these areas, rather than less ecological significance of introductions of exotics into these areas, and that careful planning and conservative considerations be the rule.

A description of 13 salmonids, 'super fish', and non-salmonids and possible interactions with Atlantic salmon is given in Appendix I, and summarized in Table 1.

4.1 Aquaculture

In regions of category (1), aquaculture should only be permitted in contained land-based facilities with indigenous species or reproductively-sterile non-indigenous species. In category (2), aquaculture of indigenous species could occur in marine cages using local stocks. Rainbow trout have already been reared in zones of category (2) without negative effects. Since there has been no apparent deleterious effects from this species on indigenous stocks, continuation of rearing this species in cages could be allowed, but sea ranching discouraged, since colonization is more likely where there is a low diversity of species or the system has been somewhat destabilized (e.g. by over-exploitation or by enrichment).

Use of non-indigenous species for aquaculture in zones of category (3) may be considered, but under the same ecological protocols, and bearing in mind that there will be escapes and probably straying to other rivers.

The sea ranching of both non-indigenous and indigenous species has dangers in that sea-ranched salmon may be exploited in mixed-stock fisheries, leading to increased fishing and over exploitation of smaller natural stocks. Until commercial fisheries have the appropriate management, sea ranching of salmon should be discouraged, except for research purposes, or for initial rehabilitation of rivers.

4.2. Selection of donor source

The selection of a donor source of stock for an introduction or transfer to the wild or to the aquaculture industry will be influenced by the content of this protocol, as well as the genetics protocol.

With respect to the receiving site, the closest donor site should be the preferred one. That choice should normally follow the progressive sequence of within watershed, nearby rivers with stocks with similar biological characteristics, or rivers with similar habitat characteristics. In category (3) it may be necessary to use more distant stocks; however these are less likely in colonizing rivers. The movement of Atlantic salmon stocks from off-continent sources to any state/province bordering the east coast of North America or the Great Lakes should not be permitted. Introductions of Pacific salmon and steelhead trout should not be permitted into new areas in eastern North America, unless it can be shown that there will be no adverse effects on Atlantic salmon.

Ecological concerns must be addressed prior to the physical movements of the stock. Study and/or documentation of the ecological concerns expressed in prior text, and others, for both the incoming fish species and the local fish species, should be undertaken. Though some documentation of early introductions and transfers has been, and will be, incomplete in some measure, the importance of amassing a database of experience cannot be overstated. Only through careful planning and documentation which is made available to all affected fisheries responsibility jurisdictions, can we avoid more of those glaring mistakes as in the past, muskellunge in the Saint John River being a recent example.

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Table 1. Stages of life history where there are potential areas for ecological impacts by selected examples of non-indigenous species on Atlantic salmon. (- = possible negative effect, 0 = probably no interaction.) Greater effects would more likely occur if the salmon population were stressed.

Species	Spawning and egg incubation	Underyearlings	>0 (Parr)	Smolts	Marine Life
Coho	-	-	-	-	-
Chinook	-	-	-	-	-
Chum	-	0	0	0	-
Pink	0	0	0	0	-
Sockeye	-	0	0	0	0
Rainbow trout	-	-	-	-	0
Cutthroat trout	0	-	-	0	0
Brook trout	0	-	-	0	0
Brown trout	-	-	-	-	0
Arctic charr	0	-	-	-	0
Lake trout	0	0	-	0	0
Non salmonids	0	-	-	-	0
Super fish	0	?	?	-	-
Dolly varden	-	-	-	-	0
Arctic grayling	0	-	-	0	0
Prosopium	0	-	-	0	0

APPENDIX I

A BRIEF DESCRIPTION OF 13 SALMONIDS, SUPER FISH, AND NON-SALMONIDS AS THEY RELATE TO POSSIBLE INTERACTIONS WITH ATLANTIC SALMON

Rainbow trout (Oncorhynchus mykiss)

On the Pacific coast the anadromous form of rainbow trout, the steelhead, appears to be an ecological equivalent of Atlantic salmon. This Pacific salmonid therefore has the potential for competing with Atlantic salmon. Both species have relatively long fluviatile stages, migrate to sea in the spring at similar sizes, and can spend a year or more at sea. Steelhead make long oceanic migrations in the North Pacific Ocean, comparable to those of Atlantic salmon in the North Atlantic, and eat comparable prey. Again similar to Atlantic salmon, steelhead trout may spawn more than once, unlike the congeneric Pacific salmons (Briggs 1953; McAfee 1966).

Both species have entirely freshwater forms, although the resident rainbow trout may be more plastic than resident Atlantic salmon (ouananiche) in that it can occupy a wider range of niches in the lotic environment (Raleigh et al. 1984). Its high acceptance for angling and eating, plasticity of habitat, relatively fast growth, and hardiness, have made it a favorite salmonid for introductions and for aquaculture, and it now has a worldwide distribution (MacCrimmon 1971). The early stages of the two species are remarkably similar in habitat preferences, behavior, and feeding (Bley and Moring 1988), such that Gibson (1981) suggested that at the juvenile fluviatile stages this Pacific salmonid was likely to have severe interactions with Atlantic salmon.

Spawning of Atlantic salmon is in the late autumn, whereas rainbow trout spawn in the late winter or early spring (Jones 1959; Smith 1973). However, both species spawn in coarse gravel in shallow fast water at the tail of pools. Data are lacking, but it may be possible for large rainbow trout to over-cut Atlantic salmon redds and cause disturbance of developing salmon alevins. Such negative interaction by rainbow trout on brown trout has been reported by Hayes (1988).

Rose (1986) observed that at emergence rainbow trout fry occupied identical habitat to that of brook trout fry (flows less than 20 $cm \cdot s^{-1}$, depths less than 40 cm) and negatively affected growth and survival of brook trout fry. During August rainbow trout fry moved into faster water (>20 $cm \cdot s^{-1}$) than brook trout fry. Everest and Chapman (1972) found that in the summer steelhead fry lived over rubble substrate in velocities of less than 15 $cm \cdot s^{-1}$ and in depths of less than 15 cm, but moved into faster and deeper water as they became larger, and as 1+ were in velocities of 15-30 $cm \cdot s^{-1}$ and in depths of 60-75 cm. Atlantic salmon fry generally occupy pebbly riffles (Symons and Heland 1978), and are usually spatially segregated from brook trout fry which occupy back waters and shallow slow water areas (Gibson 1988). It might be expected therefore that, if fry of brook trout and rainbow trout occupy similar habitat, initially rainbow trout fry would be in slower water than salmon fry. Hearn and Kynard (1986) found that, in experimental stream channels and in field experiments, 0+ salmon occupied deeper and swifter water than 0+ rainbow, and concluded that there was little interaction at the underyearling stage. However, they found that yearlings of both species occupied similar habitat, and suggested that at times there would be competition for space. There was increased use of riffle habitat by 1+ Atlantic salmon during inter-specific trials. They found that rainbow trout were better adapted to pools and were more aggressive than salmon parr. From their findings they suggested that inter-specific interactions may cause reductions in salmon production, and suggested further experiments in diverse types of habitats to test this hypothesis.

Smolts of both species may emigrate concurrently in the spring (Maher and Larkin 1955). Competition would not be expected at this time since invertebrate food is usually abundant in the spring and early summer, and habitat during emigration down the river and in the estuary would be only temporarily occupied. However, an increased number of smolts may attract more predators. On the other hand, a fixed number of predators would take a fixed number of an abundant prey, so that with increase in smolts a relatively smaller proportion of each species would be eaten. However, a possibility to consider is that large rainbow trout, which frequently are piscivorous, could inhabit the estuary and other habitats, such as lakes and pools, either as residents or as migrating steelhead, and if abundant may have the potential of reducing the numbers of Atlantic salmon smolts by predation.

Rainbow trout appear to be the least resistant of the salmonids to acid waters, their lower tolerance limit being pH 5.5-6.0 (Grande et al. 1978). This may be a limiting factor in their distribution in Newfoundland and other areas with generally acidic waters (Chadwick and Bruce 1981). In addition, rainbow trout may compete less well with other salmonids in relatively cold waters, such as in headwater streams, or in geographically colder regions (Gibson 1988), although rigorous experiments to test this hypothesis are lacking (Fausch 1988). Data are lacking to show that rainbow trout have yet successfully colonized any waters with healthy populations of Atlantic salmon, in Europe or in North America, despite many opportunities to do so, which suggests that Atlantic salmon out-compete rainbow trout. However, rainbow trout have been successfully introduced around the world in many types of habitat, and in some systems have become the dominant fish species, with no doubt negative effects on other species in the fish community. In Lake Ontario the species has successfully replaced the formerly abundant Atlantic salmon in some systems, although changes in habitat were probably the main reason for loss of the salmon. It should be considered therefore that rainbow trout could negatively affect attempts to reintroduce Atlantic salmon, or could displace Atlantic salmon from habitats which are marginal for salmon, or where salmon populations are low. Homing is strong with native steelhead (Taft and Shapovalov 1938), but straying can be expected from introduced fish or escapes from hatcheries and cage-rearing facilities (Dumont et al. 1988). The areas of possible interactions of rainbow trout and Atlantic salmon are provided in Table 1 (after References).

With these considerations in mind, introductions of rainbow trout in or close to Atlantic salmon waters should be made with caution, at least until further data are available. Areas of possible severe inter-specific interactions and where further research is needed are: (1) late underyearling and the parr stages; (2) predatory behavior of large rainbow trout with regard to parr and smolts in the river, in lakes, and in estuaries; (3) possible over-cutting of Atlantic salmon redds before the fry have emerged.

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Table 1. Possible areas of interaction of steelhead trout (Oncorhynchus mykiss) with Atlantic salmon (Salmo salar).

	Spawning, eggs and incubation	Int*	0+	Int	1+ and >	Int	Smolt	Int	Adult and marine phase	Int
Habitat	Redd in 17.8-35.6 water depth 46-76 $cm.s^{-1}$ water velocity Gravel size 2.5-10cm Redd depth 15.2-27.9cm	(-?)	Emergence at 24mm in length Shallow runs stream margins <15cm depth, <15$cm.s^{-1}$	0	Riffle and pool >15cm, >15$cm.s^{-1}$	-	River and estuary	0	North Pacific Ocean between 5°-15° surface isotherm, within the upper 25m	0?
Time	Incubation 80 days at 4.4°C plus 2 or 3 weeks to emergence		Juvenile freshwater life up to 5 years				Spring		Up to 4 years at sea	
Time of spawning	Winter or early spring (February - June)									
Food			Aquatic insect larvae in the drift and terrestrial insects on the surface			-	Invertebrates	0	Fish and invertebrates	-?
Behavior			Territorial	-	Territorial	-	Schooling	0	Schooling	0
Interaction with Atlantic salmon	Possible displacement of alevins	(-?)		0(?)	Displacement by competition				Predation of parr and smolt	(-?)

* Int = Interaction: - denotes negative effects; 0 denotes no effects.

Coho salmon (Oncorhynchus kisutch)

Coho salmon, a Pacific salmonid, has been introduced to the Great Lakes and to the east coast of North America, and is being successfully maintained by fish culture. Early attempts at introduction to east coast drainages were failures (Everhart 1966; Scott and Crossman 1973). However, introductions into the Great Lakes since 1966 have been spectacularly successful (Withler 1982). The original fish community in the areas had been considerably disturbed by over-exploitation, loss of habitat, pollution, and introductions of exotic species. Coho have filled the gap of a major predator, and have considerably restored the ecological balance, at the same time providing a valuable recreational fishery (Tanner 1988). A small breeding population has been reported in the Cornwallis River, Nova Scotia (S. Barbour, unpublished MS), probably originating from sea-ranching experiments in the New England states, but so far coho have not established themselves in any major Atlantic salmon river (Martin and Dadswell 1983).

Coho salmon are fall spawners, spawning in swifter water (0.18-0.76 $m \cdot s^{-1}$) of shallow, gravelly areas of river tributaries (Smith 1973; Buck and Barnhart 1986) from October to March, in water temperatures of 6-12°C (Briggs 1953; Shapovalov and Taft 1954). Spawning usually peaks from November to January and would likely overlap the spawning time of Atlantic salmon. The fry emerge from early March to late July, depending on spawning time, but earlier than Atlantic salmon, so that relatively larger size might give a competitive advantage. Coho salmon stay in fresh water for a few weeks to two years, depending on area. Some fry migrate almost immediately to sea or a lake, but most remain at least one year in the river. Coho fry in estuaries have better growth and survival than those in the streams (Tschaplinski 1982). Those remaining in the spawning stream take up residence in nearby shallow, gravel areas near the stream bank, preferably with large woody debris, undercut banks, and overhanging vegetation (McMahon 1983). They feed voraciously and grow quickly. They congregate in schools at first but later disperse and become aggressive and territorial or set up social hierarchies in pools (Mason and Chapman 1965; Hassler 1987; Taylor 1991). Where juvenile steelhead trout and young coho coexist, during spring and summer the steelhead are found mainly in riffle areas and the coho in pools, the segregation being brought about mainly by aggression (Hartman 1965). Under experimental conditions there is a similar segregation between young Atlantic salmon and coho, with Atlantic salmon of similar size being able to displace coho from rapids by aggression (Gibson 1981). However, coho were more aggressive than Atlantic salmon in a pool environment (Hearn 1978), and Beall et al. (1989) found that Atlantic salmon fry were more numerous in riffles when coho were present, with survival of Atlantic salmon fry being reduced in the presence of older coho fry. Gibson (1981) suggested that the niche of young coho was more similar to that of brook trout than to the niche of young Atlantic salmon. Also coho, similar to brook trout, prefer cooler water of 12-14°C (Brett 1952) than young Atlantic salmon, which have a final preferendum of 17°C (Javaid and Anderson 1967). Although young coho are mainly insectivorous, they are fairly piscivorous (Roos 1960; Ruggerone and Rogers 1992), so could prey on young brook trout and Atlantic salmon. Coho salmon smolts, similar to Atlantic salmon smolts, migrate in the spring, moving downstream in schools at twilight and at night and remain in coastal waters for some weeks before migrating to feeding areas offshore (Godfrey 1965). Along the California coast coho salmon probably remain within the limits of the Continental Shelf or within about 160 km from shore (Shapovalov and Taft 1954), but in other locations ocean types move offshore and migrate extensively (Godfrey 1965; Godfrey et al. 1975).

Adult coho salmon usually spend two growing seasons at sea before they return to fresh water to spawn, a small proportion returning as mature males after one growing season at sea. Coho salmon grow rapidly in the ocean, where they feed on both invertebrates and fish (Emmett et al. 1986). A fairly high proportion (14.9-26.8%) stray to other than their home streams (Shapovalov and Taft 1954; Salo and Bayliff 1958).

As with other introduced anadromous salmonids, increased numbers of smolts and of returning adults could attract predators and increased fishing exploitation, which would put further pressure on already depressed Atlantic salmon stocks. Possible areas of interaction of Coho salmon with Atlantic salmon are provided in Table 2 (after References).

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Table 2. Possible areas of interaction of coho salmon (Oncorhynchus kisutch) with Atlantic salmon (Salmo salar).

	Spawning, eggs and incubation	Int*	0+	Int	1+ and >	Int	Smolt	Int	Adult and marine phase	Int
Habitat	Redd in 0.1-0.54 water depth 0.18-0.76 $m.s^{-1}$ velocity; substrate size 1.3-10.2cm; late autumn to early winter in water temperatures of 4.4-9.4°C; time to hatching 86-101 days at 4.5°C.	-	0.30-1.22m depth; 0.09-<0.30 $m.s^{-1}$ velocity	0?	Velocity 0.31-0.46$m.s^{-1}$ in riffles, 0.09-0.24$m.s^{-1}$ in pools; good overhead and submerged cover preferred. Temp. 12-14°C preferred	0**	River and estuary	0?	Coastal and offshore, upper 10m, in 8-12°C	0?
Time	October-January spawning Incubation 86-101 days at 4.5°C; Emergence 2-3 weeks after hatching, but up to 10 weeks		Emergence March-July		Freshwater life up to 2 years		April-June		1-sea-winter, returning July-February	
Food			Insectivorous	0	Insectivorous & piscivorous	-	Insectivorous & piscivorous	-?	Invertebrates and fish	0?
Behavior			Schooling or aggressive	0?	Territorial or social hierarchies	-	Schooling	0	Schooling	0
Interaction with Atlantic salmon	Possible competition with location or overcutting of redds	0	Possible displacement in pool and lentic habitats; possible predation of Atlantic salmon fry							

* Int = Interaction: - denotes negative effects; 0 denotes no effects.

**0 in riffles; - in pools

Chinook salmon (Oncorhynchus tshawytscha)

The chinook salmon is native to the North Pacific drainages of Asia and North America. In North America it ranges from the western Canadian Arctic, Alaska, and British Columbia, southward to California.

This species was the first Pacific salmon to be introduced elsewhere and has probably been introduced more extensively than any of the others. From 1872 to 1930 many attempts were made to establish California stock from Maine to South Carolina, as well as in Georgia, Louisiana, and Mississippi. It was also introduced in Mexico, Argentina, Chile, Nicaragua, England, Ireland, Holland, France, Germany, Italy, Hawaii, Australia, Tasmania, and New Zealand. The only self-supporting anadromous populations that developed were on South Island, New Zealand (Scott and Crossman 1973). Starting in 1968, chinook have been maintained in the Great Lakes by stocking and with at present 15-20% by natural reproduction in the upper three lakes (Tanner 1988). Chinook salmon at present are the most popular and abundant salmonid in the Great Lakes, with an annual sport harvest in Lake Michigan of 934,000, which is approximately 48% of the salmonid catch. In 1881, substantial numbers of chinook salmon eggs went to New Brunswick, but introductions were unsuccessful. In 1985, three chinook were caught in the Annapolis River System, Nova Scotia, and two in the St. Croix River, New Brunswick. These fish were probably strays from introductions in New England (Scott and Scott 1988). In recent years a number of chinook have been caught in the St. Lawrence River, probably coming from the Great Lakes (Dumont et al. 1988).

Adult chinook enter their spawning rivers over most of the year. Many rivers have more than one run (spring to winter chinooks), each made up of fish bound for different spawning grounds. In the Fraser River they appear as early as January, reach maximum numbers in August and September, and are present in December in some years. The adults proceed up river as short a distance as the point just above tidal influence, or as much as 600 miles in the Fraser River and over 1,200 miles in the Yukon River.

Spawning time varies with time of arrival, area, and length of river migration. In the Fraser River it is July to November, July and August in the Yukon River, August to September elsewhere on mainland British Columbia and October on Vancouver Island. Chinook salmon generally spawn in larger rivers or larger tributaries, near riffles. They tend to spawn in deeper water and on larger gravel than the other Pacific salmon. The males and females are aggressive on the spawning grounds. The redd can be as much as 3.7 m long and 31 cm deep. In the Columbia River straying to other spawning grounds amounted to less than 8.4% (Major et al. 1978).

Incubation time varies with temperature, from 206 days at 1.6°C to 28 days at 18.1°C, although incubation temperatures should not exceed 14.2-15.5°C. The alevins, 20-30 mm long, remain in the gravel for 2-4 weeks while the yolk is absorbed. Some fry proceed almost directly to the estuary (Macdonald et al. 1988), but in many British Columbia stocks they remain in fresh water for a year, and those in the Yukon River for two years. The fry in fresh water school at first but later become territorial and aggressive. Fry shortly after emergence seek quiet areas such as backeddies, stream margins, undercut banks, and deadfalls where velocities are typically less than 15 $cm \cdot s^{-1}$, but adjacent to swifter flowing water of 40 $cm \cdot s^{-1}$ or more. With growth the parr move to swifter flowing water, selecting water velocities up to 60 $cm \cdot s^{-1}$ with an optimal range of 0 to <40 $cm \cdot s^{-1}$ at depths of ≥ 15 cm (Raleigh et al. 1986).

Upper lethal temperatures and preferred temperature are 25.1°C and 12-14°C (Brett 1952). Food consists of: terrestrial insects: crustacea; chironomid larvae, pupae, and adults; corixids; caddisflies; mites; spiders; aphids; Corethra larvae; and ants.

Social behavior of juvenile chinooks changes with water velocity and habitat, so they may be schooling in pools, but territorial in riffles (Reimers 1968). In stream tank experiments young chinook preferred riffle habitats (Taylor 1991).

Migration to sea takes place at various times. A temperature of 12°C is considered the upper limit for smoltification and about 8 cm the minimum size that fish can smoltify. The smolts spend some time close to shore before moving to the open ocean or lake. At sea young fish feed on invertebrates and small fish. Older chinook feed mainly on fish (97%), but invertebrates such as squid, amphipods, shrimps, euphausiids, crab larvae, and other crustaceans make up the remainder (3%).

Chinooks mature after one to five years at sea but most spend two or three years at sea. Males tend to mature earlier than females, with some returning to spawn after spending one year at sea (jacks). Chinooks grow larger than the other Pacific salmonids. Those usually seen are a maximum of 96.8 cm in length, but there is a record of an Alaska chinook of 147 cm in length, weighing 57.2 kg. Chinook salmon may range over much of the North Pacific Ocean or remain in coastal or inside waters (bays and sounds) for their entire sea life. Chinook salmon are frequently found within about 10 m of the surface and are common to depths of 100 m. Preferred water temperature ranges from 7 to 10°C and they will tolerate 2-13°C.

Interactions with Atlantic salmon could possibly occur with competition for spawning sites, although chinook would probably be the earlier spawner. Chinook fry probably use slower water than that selected by young Atlantic salmon, but as the older chinook move into faster water there could be overlap of habitat. At sea there might possibly be competition for food, depending on numbers. Possible areas of interaction of chinook salmon with Atlantic salmon are in Table 3 (after References).

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Table 3. Possible areas of interaction of chinook salmon (Oncorhynchus tshawytscha) with Atlantic salmon (Salmo salar).

	Spawning, eggs and incubation	Int*	0+	Int	1+ and >	Int	Marine phase	Int
Habitat	Average depth 32cm, velocity $0.6 m.s^{-1}$, substrate 7.6cm to 15.2cm, end of a pool	-(?)	Stream margins and quiet areas, or estuarine	0(?)	Riffles and pools in fresh water	-(?)	Both ocean ranging and coastal	0(?)
Time	July to November, in water temperatures ranging from 4.4 to 18.0°C. Incubation 206 days at 1.6°C to 50 days at 18.1°C. Emerge 3 or 4 weeks later		Fry may move directly to the estuary or remain in fresh water		Young fish may remain up to 2 years in fresh water		1-5 years	
Food			Invertebrates		Invertebrates	-(?)	Fish (97%), invertebrates (3%)	-(?)
Behavior	Aggressive	-(?)	Schooling	0	Schooling or territorial	-(?)	Schooling	(?)
Interaction with Atlantic salmon	Possible competition for spawning sites				Possible competition at the parr size		Possible competition for food at sea	

* Int = Interaction: - denotes negative effects; 0 denotes no effects.

Arctic charr (Salvelinus alpinus)

The Arctic charr has the most northerly distribution of any freshwater fish. It may be anadromous or confined entirely to fresh water. More southern populations are usually landlocked. However, a number of rivers in Ungava Bay, central and southern Labrador, and the Northern Peninsula of Newfoundland have anadromous runs of both Arctic charr and Atlantic salmon, suggesting that the two species are ecologically compatible in the fluvial environment, although competitive interactions are probable. Relative abundances of landlocked Atlantic salmon and Arctic charr in lakes, however, suggests that in some lakes salmon have a negative effect on the charr (J. Hammar, pers. comm.). V. Pepper (pers. comm.), in the course of experimental stocking of young Atlantic salmon in lakes for lake-rearing experiments, found a negative effect on condition and numbers of Arctic charr. In Scandinavia introductions of Arctic charr to lakes with brown trout have caused reductions in number and growth of the trout. Experiments showed that brown trout were more aggressive than Arctic charr, but that food was similar, so that Arctic charr reduced growth rate and numbers of trout probably by exploitation (Nilsson 1963). Svärdson (1976) reported that when Arctic charr and whitefish (Coregonus spp.) coexist, it is often to the detriment of the charr. Whitefish tend to be more effective plankton feeders and, in direct confrontation, Arctic charr is out-competed by whitefish. In laboratory experiments Arctic charr are more aggressive than brook trout or lake trout (Noakes 1980). Young Arctic charr in a river flowing into Ungava Bay were nocturnal (Adams et al. 1988), whereas young Atlantic salmon are diurnal (Gibson 1966). It is apparent that further research should be conducted to determine interactions between Arctic charr and Atlantic salmon related to climate, water chemistry, feeding behavior, and habitat, including water velocity, at different life-history stages.

Charr spawn in autumn, usually in September or October, over gravel or rocky shoals in lakes or in quiet pools in rivers, at depths of 1.0-4.5 m. Spawning takes place during the day, at temperatures around 4°C (Scott and Crossman 1973). Spawning location and time may overlap with brook trout, and hybrids occur in some Labrador rivers. (B. Dempson, pers. comm.). Cunjak et al. (1986) observed spawning of anadromous Arctic charr in a river draining into Ungava Bay from 23 September to 1 October 1985. Areas of upwelling water were selected for spawning sites. Redds were in mean depths of 62-123 cm, in heterogeneous substrates of 1-15 cm particle diameter, with mean surface velocities of 22.2-49.9 $cm \cdot s^{-1}$. Mean water temperature over the time of the study was 6.2°C, ranging from 3.7-8.3°C. In contrast, Dempson and Green (1985) reported concentrations of spawning Arctic charr in the upper section of the Fraser River, northern Labrador, during mid-October 1976-78. Redds were concentrated in groups throughout a network of channels which branched from the main river. Redds were in water 0.5-1.5 m in depth. Substrates ranged from fine and coarse sand to walnut-sized gravel approximately 4-5 cm in diameter. Charr were also observed over areas where substrates consisted of larger stones estimated to be 10-20 cm in diameter. Water temperatures were 1-3°C. This population has been used frequently in past years as a brood stock source for aquaculture research and development.

Hatching probably occurs in April with emergence of the fry by mid-July at about 25 mm. Juveniles live in the rivers for about 2-7 years, after which anadromous individuals migrate to sea during the spring and early summer. In northern Labrador rivers, juvenile Arctic charr have been found in both pool and riffle areas with the younger fish generally situated among rocks in the more protective shoreline zone.

Juveniles 10-15 cm in size have been captured in the sea, but the modal size of juveniles returning from the sea is usually around 18 cm. Ocean migrations of Arctic charr are limited in both time and space with fish spending from four to nine weeks at sea and generally travelling less than 100 km from their home rivers (Dempson and Kristofferson 1987). Occasionally, however, tagged Arctic charr have been recaptured 500-900 km from their release sites. Arctic charr are not known to overwinter at sea and the return to fresh water is characterized by the larger maturing fish entering first followed by non-maturing adults and then juveniles. Return migrations can begin in early July in Labrador, but peak runs occur in late July and early August. Anadromous charr can mature at a length of about 40 cm and 7 years of age in Labrador (Dempson and Green 1985) to 62 cm and 10 years or older in Arctic regions (Johnson 1980).

Juvenile charr feed on invertebrates but are also piscivorous at sizes above 20 cm. In general, Arctic charr are somewhat opportunistic feeders, but tend to be more selective in competitive situations. Juvenile charr have been found to feed readily on salmonid eggs (Arctic charr and brook trout) during the spawning period in Labrador.

Where Arctic charr occur sympatrically with Atlantic salmon, interactions may occur as juveniles in rivers. Experiments in a stream tank have shown that juvenile charr are territorial in riffles (R. A. Cunjak and R. J. Gibson, DFO, unpubl. data). In ponds or lakes, the charr tend to be found in deeper pelagic and profundal areas (Hammar 1987). Large charr overwintering in rivers can be piscivorous (Moore 1975). With the increased interest in aquaculture of Arctic charr at more southern latitudes, research should be conducted on possible interactions. Possible areas of interaction of anadromous Arctic charr with Atlantic salmon are provided in Table 4 (after References).

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Table 4. Possible areas of interaction of anadromous Arctic charr (Salvelinus alpinus) with Atlantic salmon (Salmo salar).

	Spawning, eggs and incubation	Int*	Juvenile freshwater life	Int	Adult and marine phase	Int
Habitat	Redds: depths 50-150cm; velocity 22-48cm.s^{-1}; substrate 1-15cm	0	Fry in sheltered areas; juveniles in pools, riffles	-(?)	Estuary and local coastal areas. Overwintering in fresh water	-(?)
Time	Spawning September-October; hatching April; emergence mid-July		2-7 years		20 years (up to 40 years). Annual return to river	
Food			Invertebrates	-(?)	Invertebrates and fish	-(?)
Behavior			Aggressive in flowing water	-(?)	Schooling	0
Interaction with Atlantic salmon		0	Possible competitive interaction with young salmon in fresh water	-(?)	Possible predation of salmon smolts in the estuary or parr in fresh water	-(?)

* Int = Interaction. - denotes negative effects; 0 denotes no effects.

Chum salmon (Oncorhynchus keta)

Chum salmon, also called autumn or dog salmon, are the second most abundant and most widely distributed of the Pacific salmon. Streams used by spawning chum extend from the Coquille River, Oregon, northward more or less continuously along the Pacific coast across Alaska, eastward along the shores of the Arctic Ocean to the McKenzie River, and westward along the Aleutian Chain. In Asia, chum spawn in streams and rivers extending from northern Kyushu, Japan, northward along the Japan Sea and Sea of Okhotsk, as well as along the Pacific coasts of Japan and Russia and the Arctic coast of Russia to the Lena River. Chum salmon are considerably more abundant in Asia than in North America.

The chum salmon has been the least used for introductions beyond its natural range. In 1955, eggs were planted in the Winisk River, a tributary to Hudson Bay, and fingerlings were liberated in the Attawapiskat River, which flows into James Bay. These attempts to establish chum salmon in Hudson and James bays failed (Scott and Crossman 1973).

Mature fish migrate to spawning rivers at times differing with location. In northern British Columbia they arrive on the spawning grounds as early as July. In the south, arrival varies from September to early January. There are distinct autumn and summer runs. In general, they are looked upon as the latest salmon to arrive on the spawning grounds in British Columbia. Chum salmon frequently spawn in tidal areas, but in some systems make extensive migrations, ascending over 1,200 miles in the Yukon. As a result of the wide spread in time and area, there is no known correlation between water temperature and spawning.

Males are aggressive on the spawning grounds. Spawning takes place over substrates ranging from medium gravel to bedrock strewn with boulders. In the latter case, eggs are released and simply fall into the crevices.

Depending on water temperature, hatching occurs from late December to late February. Emergence is in late April or early May. Chum fry spawned in short coastal streams move downstream within a day or two, but in larger river systems they remain in fresh water for up to several months (Shepard et al. 1968). However, in some short coastal streams fry stay in fresh water for extended periods (Mason 1974). Migrations to sea are mainly in April and May, but many extend through the summer. At times the fry school before they reach the sea, but they always form schools in estuarial water. They often remain near shore for several months before they disperse into the sea and are usually gone from the shore by late July or early August. Upper lethal temperature of fry is 23.8°C and preferred temperatures 12-14°C (Brett 1952).

The number of years chum salmon spend at sea before attaining sexual maturity varies from one to six, but most mature at ages 2-4 (Neave et al. 1976). Migrations follow the continental shelf with most young salmon migrating within 37km of shore, with preferred temperature range of 3 to 11°C. Temperatures below 3°C are avoided by all but Bering Sea fish. In early summer they are found from near surface to a depth of 60 m with most frequenting depths below 12 m. Later in summer they are common from surface to 25 m. Young-of-the-year chum spend most of their time in relatively deep waters that extend to depths of 95 m (Neave et al. 1976).

Chum salmon begin feeding prior to emergence from the redd. Alevins consume detritus, diatoms, cyclopoid copepods and chironomids. Fry in fresh water feed mainly on chironomids, ephemeropteran, plecopteran, and trichopteran nymphs, simuliid larvae, and terrestrial insects (Bakkala 1970). In the early stages of marine life, food varies with season and area, and includes a wide variety of organisms such as diatoms, chaetognaths, ostracods, cirripeds, mysids, cumaceans, isopods, amphipods, decapods, dipterous insects, and fish larvae. In Nanaimo Bay, fry fed heavily on the copepod Harpacticus uniremus (Healey 1982). Copepods, tunicates, and euphausiids dominate the diet of the young and of the older fish at sea. Other items eaten at sea are fishes, copepods, pteropods, and squid.

Chum salmon support primarily a high seas and coastal commercial fishery and are little sought after by the angler. It has been suggested that there are competitive interactions in the ocean between pink and chum salmon, and that the capacity of the North Pacific Ocean to grow salmon is limited (Salo 1988).

Interactions with Atlantic salmon would probably be minimal. As late fall spawners there could be competition for and overcutting of redds. Juvenile chum have a short freshwater life, but might possibly compete for food with Atlantic salmon and brook trout fry. Possible areas of interaction of chum salmon with Atlantic salmon are provided in Table 5 (after References).

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Table 5. Possible areas of interaction of chum salmon (Oncorhynchus keta) with Atlantic salmon (Salmo salar).

	Spawning, eggs and incubation	Int*	0+	Int	Marine phase	Int
Habitat	Redd area averaging 2.3 m^2, and up to 41cm deep, in a wide range of coarse substrates. Can be in tidal areas	-(?)	Freshwater and estuarine	0	North Pacific, surface to 95m, 1-15°C, 3-11°C preferred	0(?)
Time	Spawning September-January. Hatching late December to late January, 20.5mm long	-(?)	Emergence late April or early May, 33.2mm long. Fry migrate first night after emergence, or may stay up to several weeks.	0	1 to 6 years, but most mature at ages 2-4.	0(?)
Food			Invertebrates	-(?)	Invertebrates and small fish	-(?)
Behavior	Aggressive on the spawning grounds	-(?)	Schooling	0	Schooling	0
Interaction with Atlantic salmon	Possible competition for and overcutting of spawning sites		Possible competition for food		Possible competition for food	

* Int = Interaction: - denotes negative effects; 0 denotes no effects.

Pink salmon (Oncorhynchus gorbuscha)

Pink salmon are found in most tributary rivers of northeast Asia from Peter the Great Bay, north to the Lena River, and in North America from the Sacramento River, California, north around Alaska, including the Aleutian Islands, to the delta of the Mackenzie River (Scott and Crossman 1973).

In the late 1800s this species was introduced from Maine to Maryland without success. Many times, beginning in 1906 and again in 1914-18, fry were introduced into many Maine rivers with short-lived successes. In 1956 pinks collected in the fall of 1955 from the Skeena River, B.C., were introduced in Goose Creek, an Ontario tributary of Hudson Bay. This introduction failed, but some of the same brood were released into lake Superior. In 1959 a few pink salmon spawning in a Minnesota Lake Superior tributary were collected. Thereafter, principally in odd-numbered years, spawning pink salmon were observed spreading through the Great Lakes. In recent years pink salmon have been observed in tributaries to all five of the Great Lakes. They are now spawning every year. They feed on plankton and small fishes. In 1985 pink salmon were especially abundant in Lake Huron. However pink salmon in the Great Lakes are small, and although there is a small commercial fishery they are not prized as a sports fish (Tanner 1988).

Between 1959 and 1966 eggs from Indian, Glendale, and Lakelse rivers of British Columbia were planted in the North Harbour River, St. Mary's Bay, Newfoundland. By 1967 strays of this stock had spread to Nova Scotia and Labrador, and had penetrated the Gulf of St. Lawrence as far as the Great Watchichou River, Quebec. However, runs dwindled and finally disappeared (Lear 1975).

In 1983 a pink salmon was caught from the Miramichi River, N.B. (Randall 1984), indicating that the species may be spreading into the Gulf of St. Lawrence from the Great Lakes.

Adults migrate from the sea into freshwater rivers from June to September, depending on location, with spawning taking place from mid-July to late October in rivers and tributary streams. In Maine and Newfoundland spawning was between September 15-30. Spawning occurs at temperatures as high as 16°C, but spawning of later runs peaks at 10°C. The redd is built in medium-sized gravel in a water depth of about 30-60 cm.

Depending on water temperature, hatching occurs from late December to late February. Emergence is in April or early May. Almost immediately the fry descend to estuarial waters, migrating at night. Those emerging from the higher spawning grounds hide in the gravel by day, become active at night, and are displaced downstream by the current. They generally form large schools and are active in the daytime when they reach estuarial water. Young pink salmon may stay in inshore waters for several months before moving to the open sea (Levy and Northcote 1982; Levings et al. 1986). Upper lethal temperature and preferred temperature of the young are 23.9°C and 12-14°C (Brett 1952).

Pink salmon on the whole live two years, although individuals of three years of age have been reported. Two-year-old adults, after spending about 18 months in the sea, return to the spawning streams in predictable and highly segregated even-numbered-year and odd-numbered-year runs. Straying rates are high and adults have been taken in spawning streams as much as 400 miles from their original stream. Tagged adults have been captured as much as 1,700 miles from the site of tagging.

Pink salmon have not yet successfully invaded any Atlantic salmon river, despite numerous attempts at introductions. However, the success of the species in the Great Lakes suggests that colonization from this source is possible. Ecological interactions with Atlantic salmon would probably be minimal. Earlier spawning time and selection of finer gravel would suggest little interaction at this stage, although competition with spawning sites of brook trout is possible. The fry on emergence migrate immediately to the estuary, and earlier than Atlantic salmon smolts. Possible areas of interaction of pink salmon with Atlantic salmon are provided in Table 6 (after References).

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Table 6. Possible areas of interaction of pink salmon (Oncorhynchus gorbuscha) with Atlantic salmon (Salmo salar).

	Spawning, eggs and incubation	Int*	0+	Int	Marine phase	Int
Habitat	Streams with fine or medium sized gravel. Depth of water of redds 30-60cm	0	Emergence at 30-45mm and immediate migration to the estuary	0	North Pacific Ocean, but abundant in the Great Lakes	0
Time	Spawning July-October. Hatching late December to late February.	0	Mid-April to mid-May	0	18 months at sea	0
Food			Invertebrates in the estuary	0	Invertebrates and small fish	0(?)
Behavior	Territorial at the spawning grounds	0	Schooling	0	Schooling	0

* Int = Interaction: - denotes negative effects; 0 denotes no effects.

Brown trout (Salmo trutta)

Brown trout are indigenous to drainages of the eastern North Atlantic where the species is a common co-habitant with Atlantic salmon, but introductions have now given the species almost a worldwide distribution where the habitat is suitable (MacCrimmon and Marshall 1968). Similar to the situation between brook trout and Atlantic salmon, there is wide overlap of habitat between juveniles of brown trout and salmon, but brown trout are more of a pool dweller, the juvenile salmon occurring more in shallow, open fast-water areas (Jones 1975; Heggenes and Saltveit 1990). Similar to Atlantic salmon, juveniles of anadromous brown trout migrate to sea in the spring (Pemberton 1986; Lear and Day 1977).

Brown trout are autumn spawners and spawn in coarse gravel in swift water (Frost and Brown 1967; Witzel and MacCrimmon 1983; Raleigh et al. 1986). Time of spawning overlaps that of Atlantic salmon, also the two species spawn in similar type of habitat (Jones 1959). In Norway, segregation at spawning prevents superimposition of redds and there is little hybridization (Heggberget 1988). However, in Newfoundland, where the brown trout is introduced, frequency of hybridization is relatively high where the two species occur together (Verspoor 1988; McGowan 1992).

Both brown trout and juvenile salmon feed primarily on invertebrates, but larger brown trout can be piscivorous and can prey on salmon parr and smolt (Piggins 1958; Thomas 1962; Frost and Brown 1967).

Brown trout are aggressive and in running water are territorial. A number of authors have suggested that brown trout negatively affect the production of young Atlantic salmon (e.g. Lindroth 1955; LeCren 1965; Egglishaw and Shackley 1977). However, young Atlantic salmon displace brown trout in shallow, fast water conditions (Kennedy and Strange 1982; Gibson and Haedrich 1988). In Newfoundland the distribution of brown trout is limited to some rivers on the Avalon Peninsula and adjacent bays, where they are exceptionally successful in some systems and appear to have displaced Atlantic salmon in some rivers. However, Gibson and Cunjak (1986) concluded that brown trout only became the dominant species where the salmon had declined or disappeared for other reasons, or the habitat and natural fish community had been perturbed by man. In the unperturbed ecosystems Atlantic salmon were more abundant than the brown trout. However, a number of studies have shown competition between the two species with negative effects on juvenile salmon in the pool environment (Heggenes 1990). Also large anadromous brown trout are likely to eat salmon smolt in the estuary (Piggins 1958), so that introduction of brown trout into Atlantic salmon rivers is inadvisable. Some strains of brown trout are more piscivorous than others (Ferguson 1987), and should therefore not be introduced into lakes where there is lake rearing of parr or through which there would be migration of smolt. Large anadromous brown trout are occasionally caught by commercial fishermen in parts of Newfoundland as a by-catch for Atlantic salmon, but these sea trout are not sufficiently abundant in Newfoundland to provide a commercial fishery for the species.

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Brook trout (Salvelinus fontinalis)

The brook trout is indigenous to eastern North America. In its native range it is particularly abundant in Ontario, Quebec, Newfoundland and Labrador, New Brunswick, Nova Scotia, Maine, Vermont, New Hampshire and upper New York (Power 1980). It probably occurs sympatrically in all rivers with Atlantic salmon in the western North Atlantic.

Brook trout are autumn spawners, but generally spawn earlier than Atlantic salmon, although timing may overlap. Redd sites are generally over upwelling water in finer gravel than that preferred by Atlantic salmon (Witzel and MacCrimmon 1983), whereas Atlantic salmon spawn in faster water in areas of coarse gravel with down-welling current, so that interactions would not be expected related to spawning. Brook trout may eat displaced eggs which, however, would be unlikely to survive out of the redd site.

The fry emerge earlier than Atlantic salmon fry, which gives the trout an advantage in size (Randall 1982). Under some conditions the larger size gives brook trout fry a competitive advantage over the salmon fry (MacCrimmon et al. 1983). However, with naturally occurring diversity of habitat, brook trout occupy slower water in small streams, at the river's edge, than do the salmon fry, which prefer pebbly riffles, often in mid-stream, so that interactions at this stage are minimized (Symons and Heland 1978; Gibson and Dickson 1984).

In general, brook trout are pool dwellers, whereas young Atlantic salmon are most abundant in riffles, although temperature effects are also important affecting segregation (Gibson 1966; Raleigh 1982). However, there is considerable overlap of habitat and each species occupies a wider niche in the absence of the other. Without salmon present, brook trout may be abundant in riffle areas through the growing season, whereas salmon parr in pools are negatively affected by brook trout (Gibson 1973; Gibson and Dickson 1984). Brook trout are more associated with overhead cover than are young salmon. In some systems brook trout are more abundant in the smaller tributaries than in the main stem, where salmon parr may be abundant (Gibson et al. 1987).

Brook trout can be anadromous, especially where brackish water estuaries are present (Castonguay et al. 1982; Dutil and Power 1980; White 1942) and feed on crustacea and small fish in the estuarine and marine environment. Smith and Saunders (1968) successfully introduced hatchery brook trout into an estuary to supplement angling. Similarly, Gibson and Whoriskey (1980) induced anadromy in a proportion of wild brook trout removed from a non-migratory population by releasing them in an estuary below an impassable falls for trout. The experiment was repeated by Whoriskey et al. (1981), with the same results. Such enhancement should proceed with caution in salmon rivers, since increased predation on estuarine parr and emigrating smolt by large brook trout is possible.

Brook trout will prey on young Atlantic salmon when the salmon are stressed or in an unusual environment (Symons 1974), but in the natural fluvial environment predation on salmon is rare and both species primarily eat invertebrates (Thonney and Gibson 1989). However, large brook trout in lakes may be piscivorous (Power 1980). Since there are genetically different large and fast growing forms or strains (Flick 1977), strains of brook trout from other watersheds should not be introduced into a salmon river or watershed where the two forms have not evolved sympatrically. Extension of the range of Atlantic salmon into waters where brook trout occur may have negative effects on the brook trout, depending on the type of habitat. In habitats more typical for young salmon, i.e. riffles and flats, yearling brook trout numbers may be significantly reduced (Gibson 1973), but where good brook trout habitat is abundant, i.e. deep pools, especially in cooler waters, their relative numbers may not be seriously affected and salmon will be less successful. Severity of interactions will therefore depend on the type of habitats in the system (Gibson et al. [in press]).

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Lake trout (Salvelinus namaycush)

The original distribution of lake trout is in cold waters of northern North America, typically in deep oligotrophic lakes, but occurring in some northern rivers, where in Quebec the species may co-habit with young Atlantic salmon (Scott and Crossman 1973; Marcus et al. 1984).

Spawning takes place in the fall over boulder or rubble bottom in lakes, very rarely in rivers, at depths of less than 12 m but less than 37 m in the Great Lakes. The spawning act takes place after dark.

Invertebrates are eaten, especially by younger trout, but lake trout are generally piscivorous. Interactions would not be expected in fluvial habitats between lake trout and Atlantic salmon, except in some northern rivers. However, if lake trout were introduced to regions where lake rearing of salmon is important, such as Newfoundland, where lake trout do not occur, negative effects on the salmon would be expected, primarily by predation.

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OTHER FISH SPECIES for which there may be requests for introductions into regions of Atlantic salmon rivers. This list is not complete, but includes popular game species which have already been introduced beyond their native distribution.

Sockeye salmon (Oncorhynchus nerka)

The sockeye is a Pacific salmonid which spawns in the fall in pea-sized gravel in streams, but also in lakes in 0.3-9.2 m of water, the fry on emergence migrating directly to lakes (Scott and Crossman 1973) or to sea (Heifetz et al. 1989). Juvenile sockeye and the 'landlocked' form, or kokanee, are mainly pelagic, plankton feeders living in open water areas, but kokanee may derive a significant portion of their food from bottom organisms. Seaward migration of smolts occurs in the spring months of their second to fifth year of life. In the ocean sockeye are pelagic and feed on zooplankton, squid, and infrequently on small fishes. Adults usually return after two years at sea, but this varies from one to four years. Competitive effects with Atlantic salmon appear to be minimal, although probably introductions should not be encouraged in areas where lake rearing of Atlantic salmon is important.

Cutthroat trout (Oncorhynchus clarki)

Cutthroat trout are a polytypic species consisting of several geographically distinct forms. Coastal forms of this Pacific salmonid may be anadromous, whereas inland forms may be lake or stream dwelling (Hickman and Raleigh 1982). Similar to rainbow trout, spawning is in the spring, taking place in small gravelly streams. In some areas fry move directly out of small streams into the larger river or into a lake. The habitat of the cutthroat trout consists of gravelly, lowland, coastal streams and lakes, inland alpine lakes and small rivers, and estuaries or the sea near shore. Food of this species consists mainly of insects, both aquatic and terrestrial, but small fishes form an important part at times. Brook trout have severely decreased the range and numbers of cutthroat where brook trout have been introduced into the habitat (Griffith 1988), suggesting that the niches of these two species are similar. Juvenile cutthroat trout are common in riffles (Glova 1987), the habitat preferred by young Atlantic salmon. Estuarine cutthroat can be piscivorous (Johnston 1982). Competitive and predatory effects with Atlantic salmon are unknown, but might be expected.

Dolly Varden (Salvelinus malma)

This species is found in the fresh and salt water of western North America and eastern Asia. There are anadromous and non-anadromous populations, although the anadromous fish remain close to shore near the river mouths.

Like other charrs, the Dolly Varden is a fall spawner. Spawning takes place during the day and, to a lesser degree, at night in rivers of moderate current with a bottom of medium to large gravel and at water temperatures near 7.8°C. In non-anadromous populations the young may spend from several months to three to four years in streams, moving then to a lake just as the anadromous stocks move to sea.

Habitat of the young for three to four years is the gravelly spawning stream in which they were spawned. The adults are found in cold lakes, gravelly to rather muddy rivers, and in the sea.

Summer food of stream-resident young is made up of adult and immature insects, snails, and leeches. Salmon eggs and insects are important in the fall. Adults are also piscivorous and possibly would be competitors and predators of young Atlantic salmon if successful introductions were made, especially in lakes and in estuaries (Lagler and Wright 1962).

'Super fish'

Fish that are biologically manipulated to be reproductively incapacitated, so that somatic growth does not slow with maturation of the gonads, are sometimes called 'super fish'. The usual technique for production of non-maturing fish requires two generations.

Natural salmonid fish populations consist of females, with two X chromosomes, and males with an X and a Y chromosome. Since male fish generally are undesirable in aquaculture operations, due to earlier maturation than females, resulting in deterioration of flesh quality, aquaculturists prefer to work with all female fish for cage rearing. Fish are often treated to eliminate males from the aquaculture stock. In the first generation, fry are treated with male hormone to induce sex reversal of females. This results in females being converted to males so that, when they mature, they will produce 'female' sperm. Normal genetic males must be removed from this mixed-sex population to avoid introducing any normal males into the next breeding cycle. This is done by selecting individuals from the sex-reversed population at the time of fertilization, dissecting, extracting and examining the gonad.

Typically, normal testes from genetic males are readily distinguishable by visual examination and discarded. Sex reversed, 'female' testes are deformed and often have vestiges of an ovary attached. These testes have only X chromosomes, and therefore, when spermatozoa are used to fertilize normal eggs, that also have only X chromosomes, the result is fertilized eggs that will produce only female fish.

An all-female population of fish is useful in itself in that females mature later than males and therefore grow to a larger size before the maturation process starts to erode flesh quality. All-female fish can be reproductively incapacitated to avoid maturation and therefore will continue to grow throughout their life. This is accomplished by fertilizing normal eggs with female sperm and then disrupting the normal cell division process with some form of environmental perturbation, typically temperature or pressure shock. This disruption of the normal meiosis process results in a fish with three sets of chromosomes rather than the normal two sets. These fish are called triploids.

If genetic males are not removed from the broodstock before attempting the triploidy process, both triploid males and females will be produced. While a triploid female does not develop any significant gonad, triploid males do undergo sexual development. Such males develop the reproductive behaviour of normal males and, while they do not develop sperm ducts and therefore can not participate in spawning, they can disrupt the spawning of wild fish by interfering with spawning pairs. If the testes of triploid males are extracted inadvertently, and used to fertilize normal eggs, all such eggs will die in the early developmental stages. A possible danger resulting from the process of inducing triploidy is that some fish will remain diploid and be reproductively viable.

Triploid fish are most common in aquaculture operations. However, such triploid, non-reproductive, all-female fish also are of interest for commercial and recreational fisheries. In the Great Lakes, chinook 'super fish' are being released with the hope of providing enormous trophy fish. These 'super fish' are likely to be predators of parr, smolt, and post-smolt in lakes and at sea.

Non-salmonid fish species

Popular stream fish with anglers, and closely allied to salmonids, are Arctic grayling (Thymallus arcticus) and mountain whitefish (Prosopium williamsoni).

Grayling spawn in the early spring over gravel in streams, but no redd is prepared. Their general habitat is clear waters of large, cold rivers, rocky creeks, and lakes, and are usually associated with Pacific salmonids. Food of the young is mainly zooplankton with a gradual shift to immature insects, mainly mayflies, caddisflies and midges, with increase in size. The adults consume a very broad assortment of invertebrates, but mainly aquatic and terrestrial insects, including to those mentioned, bees, wasps, grasshoppers, ants, and a variety of beetles. Other items eaten are small quantities of fishes, fish eggs, lemmings, and planktonic crustaceans. Similar food items to those eaten by young Atlantic salmon suggest that if habitat and feeding times were similar, competitive effects would be possible.

Mountain whitefish spawn in late fall or early winter over gravel or gravel and rubble, in lakes in streams, but no redd is prepared. It inhabits lakes and larger rivers, apparently preferring large streams to small. It is primarily a bottom feeder consuming a variety of organisms, especially aquatic insect larvae such as those of mayflies, stoneflies, caddisflies, and midges, small molluscs, and, on occasion, fishes. It will also feed on plankton and surface insects. The species eats salmonid eggs, but these are displaced eggs, drifting in the stream. It is reputed to compete with Pacific salmonids in its natural habitat, so probably would do so with Atlantic salmonids. This might be considered an unlikely species to introduce, but it provides better angling than the lake whitefish (Coregonus clupeaformis), which has been introduced to Newfoundland.

As discussed earlier, the greatest danger from introductions to Atlantic salmon in some regions is by non-salmonids, such as cyprinids, esocids, percids, centrarchids, perchichthids, etc., some of which would eliminate salmonid production from lentic habitats which are major areas of Atlantic salmon production in Newfoundland, Labrador, parts of Quebec, and elsewhere.

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