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REMARKS

Bob,

Enclosed is a copy of the 1972 Atlantic Salmon agenda and several reprints. The Symposium will be published through the International Atlantic Salmon Foundation. Contact

Mr Wilfred M Carter, Exec. Dir.
P.O. Box 429
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~~G. Wedemeyer~~

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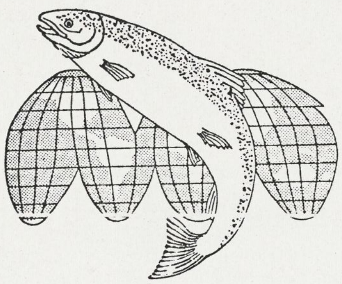
INTERNATIONAL ATLANTIC SALMON SYMPOSIUM

Management, Biology and Survival of the Species



September 20 - 22, 1972

Huntsman Marine Laboratory
St. Andrews, New Brunswick
Canada

sponsored by

THE INTERNATIONAL ATLANTIC SALMON FOUNDATION
New York, N.Y. St. Andrews, N.B.

and

THE ATLANTIC SALMON RESEARCH TRUST
Farnham, Surrey, England

INTERNATIONAL ATLANTIC SALMON SYMPOSIUM

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The Atlantic Salmon Association, Canada
The Miramichi Salmon Association, Canada
The British Field Sports Society, U.K.
The Salmon and Trout Association, U.K.
Sport Fishing Institute, U.S.A.

GENERAL INFORMATION

All Symposium Activities will take place at the Algonquin Hotel unless otherwise indicated.

REGISTRATION

General — $20.00.

Ladies (accompanying participants) — $12.00. Covers all activities of the Ladies Program except the Lobster Luncheon on Thursday, September 21.

Student — $10.00.

BANQUET, SEPTEMBER 21: $10.00 per person.

LUNCHEON, SEPTEMBER 20: $4.00 per person. (Included in the room rate for Algonquin Hotel guests).

Tickets for the Banquet and Luncheon may be prepaid or obtained at the Registration desk.

ACCOMMODATIONS

Algonquin Hotel — Single Room . . . $31.00 per person per day. Double Room . . . $26.00 per person per day. (Includes all meals but the Banquet).

Huntsman Marine Laboratory Residence — $10.00 per person per day. Dormitory style. Includes all meals except lunch September 20 and evening meal September 21.

Algonquin Hotel charges are payable directly to the Hotel upon departure. H. M. L. Residence charges are payable to The International Atlantic Salmon Foundation.

TRANSPORTATION

A Symposium representative will be at the Fredericton and Saint John airports September 19 to meet all incoming flights and to provide transportation to St. Andrews at a nominal cost. Guests wishing to avail themselves of the Symposium transportation service should so indicate on their registration form, giving arrival time, flight number and airport.

Commercial buses run from Saint John to St. Andrews at 7:45 a.m. and 9:00 p.m. There are no direct bus connections between Fredericton and St. Andrews.

Car rental firms are located at both airports. Advance reservations are recommended.

A transatlantic charter flight between England and Saint John is being arranged. The round-trip fare is estimated at £110. For details contact: The Atlantic Salmon Research Trust, Morley House, 29 South Street, Farnham, Surrey, England.

Distances to St. Andrews

From	*Mileage*	*From*	*Mileage*
Fredericton, N.B.	78	Boston, Mass.	380
Saint John, N.B.	68	New York, N.Y.	600
Bangor, Maine	125	Montreal, Que.	500

TOURS

Two tours providing an opportunity to see local scenery and an overview of Atlantic salmon projects will be offered following the Symposium; one to Quebec and another to the Maritimes. Departure from St. Andrews —September 23. Return to St. Andrews—September 28.

Cost: Approximately $150 per person, including transportation, accommodations, guided tours, seminars, evening meals. Final charge will be reduced as additional registrations are received.

Deadline for Registrations: July 15.
Deposit: $35.00 per person. Payable July 15.
Refundable to August 15.
Registrants will be notified of final cost by July 31.
Balance due: on or before September 1.

INFORMATION

During the Symposium—Telephone (506) 529-8823.
All other times — IASF Offices — (506) 529-3818.

SCHEDULE

TUESDAY, SEPTEMBER 19

The Registration Desk in the Algonquin Hotel opens at 10:00 a.m. and will remain open throughout the Symposium for late registrations and general information.

WEDNESDAY, SEPTEMBER 20

9:00 a.m. OPENING PROCEEDINGS — *Casino*

OFFICIAL OPENING:

THE HONOURABLE HEDARD J. ROBICHAUD
Lieutenant Governor of New Brunswick

Keynote Address:

THE HONOURABLE JACK DAVIS, P.C., M.P.,
Minister of the Environment and Minister of Fisheries for Canada

10:00 a.m. SESSION ONE — *Casino*

EFFECTS OF MAN AND A CHANGING ENVIRONMENT UPON THE ATLANTIC SALMON

11:00 a.m. **Sherry and Coffee Party—*Private Dining Room*

12.15 LUNCHEON — *Main Dining Room*

Address:

PROFESSOR D. A. CHANT
Chairman, Department of Zoology, University of Toronto

"THE VALUES OF DIVERSITY"

2:15 p.m. SESSION TWO — *Casino*

PHYSIOLOGY

**Ladies Program

THURSDAY, SEPTEMBER 21

8:45 a.m. SESSION THREE — *Casino*

ECOLOGY

12:15 p.m. **Ladies Luncheon
Conley's Lobster Restaurant

1:30 p.m. **Tour of Huntsman Marine Laboratory and Fisheries Research Board Station, St. Andrews

1:45 p.m. SESSION FOUR — *Casino*

AQUACULTURE

6:15 p.m. RECEPTION — *Cocktail Lounge and Foyer*

7:15 p.m. BANQUET — *Main Dining Room*

Address:

HIS EXCELLENCY THE HONOURABLE ADOLPH W. SCHMIDT
Ambassador of the United States of America to Canada

FRIDAY, SEPTEMBER 22

8:45 p.m. A SESSION FIVE — *Casino*

ENVIRONMENTAL ENGINEERING AND FISHERY ECONOMICS

9:00 a.m. **Day Cruise to Campobello or Cruise up the St. Croix River

1:45 p.m. SESSION SIX — *Casino*

CONSERVATION AND FISHERIES

5:30 p.m. CLOSING REMARKS — *Casino*

Two rooms off the Main Lobby of the Algonquin Hotel have been set aside for industry exhibits, book displays, and the distribution of papers on subjects related to the Symposium.

**Ladies Program

PROGRAM

SESSION ONE

THE EFFECTS OF MAN AND A CHANGING ENVIRONMENT UPON THE ATLANTIC SALMON

CHAIRMAN: W. M. CARTER
Executive Director,
The International Atlantic Salmon Foundation,
St. Andrews, New Brunswick, Canada

1. ATLANTIC SALMON — AN ENDANGERED SPECIES OR A RESOURCE FOR THE FUTURE.
DONALD L. MCKERNAN,
Coordinator of Ocean Affairs and Special Assistant to the Secretary, United States Department of State, Washington, D.C.

2. RECENT DEVELOPMENTS AFFECTING ATLANTIC SALMON IN THE BRITISH ISLES AND EUROPE.
P. J. LIDDELL
Chairman, The Association of River Authorities for England and Wales, Carlisle, England.

3. THE PROBLEM OF ATLANTIC SALMON PRODUCTION AND USE IN NORTH AMERICA.
A. W. H. NEEDLER,
Executive Director, Huntsman Marine Laboratory, St. Andrews, New Brunswick, Canada.

SESSION TWO

PHYSIOLOGY

CHAIRMAN: John M. Anderson,
Director General, Research and Development, Fisheries Service, Department of the Environment, Ottawa, Canada.

1. ROLE OF HORMONES IN THE LIFE OF ATLANTIC SALMON
   D. R. Idler,
   Director, Marine Sciences Research Laboratory, Memorial University, St. John's, Newfoundland, Canada.

2. SIGNIFICANCE OF CARBOHYDRATE METABOLISM IN YOUNG ATLANTIC SALMON TO MAN-MADE ENVIRONMENTAL STRESS.
   C. A. G. Wendt,
   Section Head, Bureau of Freshwater Fisheries, Goteburg, Sweden.
   Richard L. Saunders,
   Scientist in charge of Physiological Studies, FRBC*

3. IMPACT OF CHEMICAL POLLUTANTS ON ATLANTIC SALMON IN NORTH AMERICA.
   Paul F. Elson,
   Program Head, Anadromous Group, FRBC*
   Alfred L. Meister,
   Chief Biologist, Atlantic Sea Run Salmon Commission, Bangor, Maine, U.S.A.
   Richard L. Saunders,
   Scientist in charge of Psysiological Studies, FRBC*
   John B. Sprague,
   University of Guelph, Guelph, Ontario, Canada.
   Vlado Zitko,
   Research Chemist, FRBC*

4. MIGRATION-ORIENTATION OF ATLANTIC SALMON
   – Aivars B. Stasko,
   Research Scientist, FRBC*
   Arnold M. Sutterlin,
   Research Scientist, FRBC*
   Sentiel A. Rommel,
   Post Doctorate Fellow, FRBC*

5. SHIFT IN PROPORTION OF HAEMOGLOBINS DURING GROWTH OF *SALMO SALAR L.*
   Henri J. A. Koch,
   Professor, Zoological Institute, University of Louvain, Belgium.

* Fisheries Research Board of Canada, St. Andrews, New Brunswick

SESSION THREE

ECOLOGY

CHAIRMAN: A. E. J. Went,
Inspector of Fisheries and Scientific Advisor, Department of Agriculture and Fisheries, Dublin, Ireland.

1. THE IMPORTANCE OF SPAWNING STREAM ASSESSMENT IN SALMON MANAGEMENT
   Derek H. Mills,
   Professor of Freshwater Ecology and Fisheries Management, Department of Forestry and Natural Resources, University of Edinburgh, Scotland.

2. PRODUCTION OF SALMON SMOLTS UNDER NATURAL CONDITIONS IN DEVON RIVERS
   Francis J. Nott,
   Fisheries and Pollution Preservation Officer, Devon River Authority, England.

3. DISPERSION OF HATCHERY REARED SALMONIDS IN A MOUNTAIN STREAM
   M. J. Bulleid,
   Senior Biologist for North Western Region af Central Electricity Generating Board, Wales.

4. INTERACTIONS BETWEEN BROOK TROUT AND JUVENILE ATLANTIC SALMON
   R. John Gibson,
   University of Waterloo, Waterloo, Ontario, Canada.

5. THE ROLE OF NUTRITION IN GROWTH AND SURVIVAL OF ATLANTIC SALMON
   Eva Bergstrom,
   Head, Division of Fisheries Biology, The Salmon Research Institute, Alvkarleby, Sweden.

6. EVALUATION OF QUALITY IN ATLANTIC SALMON ANGLING
   William C. Hooper,
   Fishery Biologist, Fish and Wildlife Branch, Department of Natural Resources, Fredericton, New Brunswick, Canada.

SESSION FOUR

AQUACULTURE

CHAIRMAN: LAUREN R. DONALDSON
Professor, School of Fisheries, University of Washington, Seattle, Washington, U.S.A.

1. ADULT RETURNS TO DATE FROM HATCHERY REARED ONE-YEAR-OLD SMOLTS
HANS H. PETERSON,
Product Manager, Astra-Ewos Products, Astra Chemicals Ltd., Mississauga, Ontario, Canada.

2. SMOLT REARING TECHNIQUES, STOCKING AND TAGGED ADULT SALMON RECAPTURES IN ICELAND
THOR GUDJONSSON,
Director, Institute of Freshwater Fisheries, Reykjavik, Iceland.

3. REARING SALMON SMOLTS IN MOUNTAIN LAKES TO SUPPLEMENT SALMON STOCKS
GRAEME S. HARRIS,
University of Liverpool, Liverpool, England.

4. A MODEL FOR GENETIC SELECTIVITY OF SALMONID FISHES FOR MANAGEMENT PURPOSES
CLIFF MILLENBACH,
Chief, Fishery Management Division, Department of Game, Olympia, Washington, U.S.A.

5. A DISCUSSION OF NORWEGIAN SALMON FARMING
DAG MOLLER
Havforskningsinstuttet, Bergen, Norway.

SESSION FIVE

ENVIRONMENTAL ENGINEERING AND FISHERY ECONOMICS

CHAIRMAN: CHARLES H. CLAY,
Coordinator of Lake Projects. FAO of the United Nations, Rome, Italy.

1. ENVIRONMENTAL ENGINEERING AND MONITORING IN RELATION TO SALMON MANAGEMENT
LESLIE STEWART,
Fishery Officer, Lancashire River Authority, Lancaster, England.

2. THE EXPLOITS RIVER DEVELOPMENT PROGRAM FOR ATLANTIC SALMON IN NEWFOUNDLAND
V. R. TAYLOR,
Chief, Resource Development Branch, Fisheries Service, St. John's, Newfoundland, Canada.
B. R. BAULD,
Chief Engineer, Resource Development Branch, Fisheries Service, St. John's, Newfoundland, Canada.

3. PULP MILLS AND ATLANTIC SALMON — CAN THEY CO-EXIST?
RICHARD ROW,
Department of the Environment, Environmental Protection Service, Halifax, Nova Scotia, Canada.

4. ECONOMIC PRINCIPLES FOR MANAGEMENT OF ATLANTIC SALMON — SAINT JOHN RIVER BASIN
N. H. MORSE,
Department of Economics, Dalhousie University, Halifax, Nova Scotia, Canada.
A. G. DEWOLF,
Department of Economics, Dalhousie University, Halifax, Nova Scotia, Canada.

5. AUTOMATIC METHODS OF MEASURING SALMON POPULATIONS
J. M. HELLAWELL,
Natural Environment Research Council, Water Pollution Research Laboratory, Stevenaghe, Herts, England.

SESSION SIX

CONSERVATION AND FISHERIES

CHAIRMAN: J. W. JONES,
Department of Zoology, University of Liverpool, Liverpool, England.

1. SALMON MANAGEMENT — MYTHS AND MAGIC
   G. POWER,
   Professor, Department of Biology, University of Waterloo, Waterloo, Ontario, Canada.

2. OCEANIC DISTRIBUTIONS AND MIGRATIONS OF ATLANTIC SALMON
   A. W. MAY,
   Advisor, Strategic Planning Branch, Fisheries Service, Department of the Environment, Ottawa, Canada.

3. THE WORK OF THE ICES/ICNAF JOINT WORKING PARTY ON NORTH ATLANTIC SALMON
   B. B. PARRISH,
   Chairman, ICES/ICNAF Joint Working Party on North Atlantic Salmon, Marine Laboratory, Aberdeen, Scotland.

4. INTERNATIONAL LAW AND ANADROMOUS FISH CONSERVATION
   W. H. MACKENZIE,
   Special Projects Assistant, The International Atlantic Salmon Foundation, St. Andrews, New Brunswick, Canada.

5. SALMON FISHERY MANAGEMENT ON A SCOTTISH RIVER (NORTH ESK)
   J. R. W. STANSFELD,
   Chairman, North Esk District Salmon Fishery Board, Montrose, Scotland.

6. RECREATIONAL ASPECTS OF SALMON FISHING IN SCOTIAND
   Speaker to be announced — British Field Sports Society.

CLOSING REMARKS

VICE ADMIRAL SIR HUGH MACKENZIE, K.C.B., D.S.O., D.S.C.

REGISTRATION FORM

Tear off and mail to: ATLANTIC SALMON SYMPOSIUM
THE INTERNATIONAL ATLANTIC SALMON FOUNDATION
P.O. Box 429, ST. ANDREWS, N.B., CANADA

Name ....

Address ....

....

Affiliation ....

Title ....

I will be accompanied by ....

Forward .... Additional copies of the Symposium Booklet.

Forward .... Copies of the Maritimes Tour Brochure.

Forward .... Copies of the Quebec Tour Brochure.

Register .... (number of persons) for the Quebec Tour,
Single Room ☐ Double Room ☐

Register .... (number of persons) for the Maritime Tour.
Single Room ☐ Double Room ☐

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H.M.L. Residence ☐

Arrange transportation on September 19 from ....
airport to St. Andrews. Arriving .... (Time)
.... (Flight No.)

I enclose $.............................. (Canadian funds) for:

1. Registration Fee ....
2. Tour Deposit ....
3. Banquet ....
4. September 20 Luncheon ....
5. H.M.L. Residence Accommodations ....

Please make all cheques and money orders payable in Canadian Funds to

THE INTERNATIONAL ATLANTIC SALMON FOUNDATION

SESSION 5

ENVIRONMENTAL ENGINEERING AND FISHERY ECONOMICS

ABSTRACTS

Environmental Engineering and Monitoring in Relation to Salmon Management

by

L. Stewart

The paper is based on information obtained from the electric monitoring of over 40,000 salmon migrating under natural circumstances in rivers and estuaries. The criteria for the construction of electric fish-diversion screens for major water supply intakes from natural lakes and rivers are discussed, together with the use of electrically operated fish lifts for safeguarding migratory fisheries, and fishery problems related to estuary barrages and criteria for their design to maintain fish migration. The fresh water requirements of salmon in estuaries and rivers are considered, in addition to the results of investigations into the velocity of water in relation to river flows, tidal influences and moon phases as affecting salmon migration in estuaries and rivers. Finally, the effect of major river water transfers from one catchment to another and the effects on migratory fish in cases where river flows are regulated in volume are described.

Automatic Methods of Monitoring Salmon Populations

by

J. M. Hellawell

The conservation of existing salmon stocks is largely based upon arbitrary fishery regulations. The collection of accurate census data is an essential prerequisite to the scientific management of salmon populations; primarily as a research tool for formulating policies and subsequently as an aid to effective policy implementation. Automatic fish-counters should provide the necessary data.

Ideally a counter should not affect the behaviour of the fish nor interfere with their free passage up or downstream. It should record only fish movements and be unaffected by other objects in the water. It should register the time, direction of movement and the size of the fish. The cost should be low and it should be possible to site the counter easily in any part of the river system but especially near the estuary if total counts are to be obtained.

~~In practice it has been~~ found to be almost impossible to design a counter which incorporates all or many of these characteristics. Most counters work within relatively small physical dimensions so that several units are required within relatively small physical dimensions so that several units are required to cover wider rivers and often costly ancilliary engineering work is necessary. Some reduction in cost may be made by taking advantage of existing weirs and dams but these may be far from ideal. It is usually impossible to site a counter so that free passage is provided yet circulation and repeated counting are avoided.

Several different principles have been employed in counter design but the electrical resistivity and sonar methods have shown greatest promise. The former detects the passage of a fish by recording changes in the resistivity of the water as the fish passes over or between electrodes. The latter utilises echoes from fish passing through high-frequency sound beams. The characteristics of the different patterns of counter currently available are reviewed.

During development a counter must undergo thorough testing in the field. It is essential that an accurate independent count should be made with which the performance of the automatic counter may be compared. Ultimately this depends on human observers but good observation conditions are not easily provided nor can one discount the problem of fatigue. A partial solution has been found: the counter is made to trigger a camera whenever it is actuated and in this way a photographic record of the counted object is obtained. The extent and nature of the false counts are thus discovered but it is not possible to estimate the proportion of salmon which are missed. The technique has been extended to compare counters. A resistivity counter was used to trigger a camera and the performance of a sonar counter was noted. This too is only a one-sided test but the checking is performed automatically which is of great value in a protracted run of fish. All testing, especially visual checking, is facilitated by dense runs of fish but these cannot usually be had in order.

The purely economic value of counters is not easily predicted; they are probably best regarded as a form of insurance. Installation costs may be small in comparison with the value of the fishery but the recurrent cost of operating personnel may be high. If increased fishing intensity is sanctioned as a result of counter installation the increased revenue could cover the cost of operation.

A Program for Increased Atlantic Salmon (Salmo salar) Production on a Major Newfoundland River

by

V. R. Taylor and B. R. Bauld

The many hundreds of rivers and streams on the island of Newfoundland are almost without exception, to the extent that they are accessible to anadromous fishes, populated by sea-run Atlantic salmon (Salmo salar). Many, however, have been denied this access to a greater or lesser degree by natural barriers (Falls and rapids) and, in recent times, by man-made obstructions (dams, pollution). The Exploits River, largest on the island of Newfoundland has, historically, been accessible to salmon for less than 20% of its watershed area of about 4,400 sq. miles. Recent decades have seen additional man-made barriers, including pollution, threaten to diminish even the existing resource. This paper briefly describes a long-term development proposal which, in its first phase, should increase the total adult salmon production of the Exploits River by about 6-fold (from a present estimated average annual production of 5,000 adults and, if shown economically and biologically feasible, in a second phase double this again. Obstacles to such development, and proposed solutions, are described.

Pulp Mills and the Atlantic Salmon--

Can They Co-Exist?

by

R. A. Row

Of the 17 pulp and paper mills in the Maritimes, 11 are located on valuable or potentially valuable Atlantic Salmon streams. These eleven mills together discharge 210 million gallons of wastes, only of which 52 are treated. This is equivalent to a waste which would be discharged by a city of 7 million. Those mills which make up the pulp and paper industry in the Maritimes encompass several types of pulping processes but have certain waste characteristics such as toxicity and high oxygen demand in common. Biological waste treatment can remove this toxicity and oxygen consuming organic material, and the effluent so produced is much more acceptable for discharge to the aquatic environment. To date the federal and provincial governments in cooperation have successfully negotiated with 13 mills for adequate treatment facilities. Discussions are about to begin with the others to ensure that their wastes comply with recently promulgated Pulp and Paper Regulations and applicable provincial legislation.

Groundwood mills constitute the major remaining problem with respect to development of waste treatment technology for this type of mill produces a toxic effluent although no chemicals are added in the pulping process. This groundwood mill toxicity problem is apparently unique to the Maritimes region and a method must be found for adequately treating the waste. Biological treatment has been shown to be effective, but a cheaper method might well exist.

Economic Principles for the Management of Atlantic Salmon - St.John River System

by

N. H. Morse and A.G. DeWolf

Management of fish stock, such as Atlantic Salmon, requires that both supplying of the stock (protecting, rearing, etc.) and harvesting of it generate economic information on which to base decisions. Such is generally not now the case, and as a consequence decisions are made more or less arbitrarily perhaps on grounds either to conserve the stock or in response to different, often conflicting, interests. There is no way of determining whether this kind of regime will move towards a social optimum or away from it. The amount of tranquility or of hostility which it generates is a very inadequate or ambiguous index by which to judge its success or failure.

The position is taken that a critical factor in the development of a management plan consistent with economic principles broadly interpreted is the conditions of access afforded to users of the fish stock. The bulk of the literature tends to neglect this crucial issue which is concerned with institutional arrangements surrounding utilization of the stock in the first instance. Accordingly, attention is focused on the nature of the good, or of the activity in question in order to explore whether other institutional arrangements, in particular an explicit form of market structure, would be feasible.

It is concluded that the good is such that resort to a market system is technically feasible, although a range of new problems can be anticipated. Unless changes in this direction can be accomplished it is inferred that management cannot unambiguously claim to have achieved either a first or a second best position and may only reach one that is considerably lower.

G. ~~Wedemeyer~~

SESSION 3

ECOLOGY

ABSTRACTS

Production of Salmon Smolts under Natural Conditions in Devon Rivers

by

F. J. Nott

This paper covers the production of salmon smolts under natural conditions. The characteristics of the rivers in which they have been produced are given and special emphasis is attached to the River Dart which is the main river system now reviewed. As with most rivers the Dart receives a certain pollution loading and supplies water to industry and the general population within a radius of 30 miles approximately.

The investigation, details of which are enumerated in this paper, covers the period 1965 to 1971 and shows how a smolt population can be estimated.

Spawning stream assessment on the River Tweed with a view to management

by

Derek Mills

During the last 150 years the salmon stocks in the Tweed have been subjected to a variety of controlling factors including pollution and poaching. The river is now almost free from pollution and poaching is insignificant. However, the effects of forestry, agriculture and water abstraction are likely to have an increasing effect on the river and its fish stocks. As other controlling factors, such as U.D.N., the high seas salmon fishery and the local coastal drift net fishery, are also operating it is essential to maximise production from the existing spawning areas. This implies sensible management which requires an understanding of the reasons for the preferences of migratory fish for certain streams. The value of a number of potential and existing spawning streams is therefore being considered from an assessment of their physical characteristics.

Dispersion of 1+ Hatchery Reared Atlantic Salmon

(*Salmo salar*) stocked into a fishless stream

by

M. J. Bulleid

The study area; 3500 ft. (1272m.) in length average width 6 ft. (2.18m.) is situated on the River Nant-Sere, a headwater tributary of the River Usk which rises in the Welsh county of Breconshire and enters the Bristol channel near Newport, Monmouthshire, Great Britain.

360 1+ hatchery reared salmon were stocked into the study area in June, 1968 and a similar number one year later. In both years the fish were planted into the same pool at a calculated density for the whole study area of 49 salmon per 100 m^2.

The survival of the planted stock within the area up to the end of November was 73.5% in 1968 and 62.7% in 1969. The lower survival figure in 1969 may be due to a poorer dispersion rate in that year. The dispersion in 1968 was considerably better than in 1969. However, few of the planted salmon migrated upstream in either year (4 out of 720, 0.55%) and the principal direction of migration was downstream. In 1968 86.2% had dispersed from the planted 100 ft. (36.3m.) section by November, but only 67% by the end of the same month in 1969.

Under the conditions which existed in the River Nant Sere; fishless low level of bird predation, 1+ salmon stocked in June should be planted at a density of 16-20 per $100m^2$ every 200 yards (218 m.) of river length and allowance should be made for downstream movement only.

Interactions of Juvenile Atlantic Salmon (*Salmo salar* L.) and Brook Trout (*Salvelinus fontinalis* (Mitchill))

by

R. John Gibson

The seasonal distributions of brook trout and juvenile Atlantic salmon were compared below two waterfalls on the Matamek River, on the north shore of the Gulf of St. Lawrence, Quebec. Trout and salmon cohabited below the "second falls", but only trout occurred below the "fifth falls". At the second falls both species were found close to the rapids in early summer, when food is abundant, but in mid-summer, when food is scarcer, salmon were abundant close to the falls, but trout had moved away from the rapids and were few. At the fifth falls, trout moved towards the falls in early summer in the same way as below the second, but remained abundant close to the rapids all summer. Stream tank experiments showed that salmon were more aggressive than trout. Interactive segregation therefore occurs between the two species when food is becoming limited. The probable mechanisms are: 1) exploitation, with salmon parr being better adapted for a fast water flow, and trout for a somewhat slower water velocity; and 2) territoriality, with salmon parr being more aggressive, and with a scarce food supply, tending to drive small trout from the rapids. Populations were estimated at about 3536 trout below the fifth falls, and about 1144 trout and 972 salmon parr below the second. The greatest difference in the relative numbers of trout was with the yearlings, which were slightly smaller than 2+ salmon parr.

The Role of Nutrition in Growth and Survival of Young Hatchery Reared Atlantic Salmon

by

Eva Bergstrom

Diets containing as much as 16% of fat (a mixture of marine oils and soy lecithin) gave good growth and survival in Atlantic salmon especially during the first summer. Feeding a diet of this type throughout the first year of rearing will probably make it possible to obtain a large percentage of the fish as one year old smolts without the use of heated water.

Shrimp meal, hydrolysed feather meal and soybean were used as substitutes for part of the protanimal with good results. Shrimp meal improved the colour of skin and ovaries of the fish. A mixture of feather meal + soybean meal seemed to promote growth, probably because of the addition of sulphur-rich amino acids obtained from the feather meal.

No fatty infiltration of the livers was noticed in fish fed as much as 16% of fat; on the contrary a high content of the unsaturated oil mixture in the diet seemed to lower the amount of liver lipids. Replacing cereals by shrimp meal in the diet also caused a reduction of the total amount of liver lipids.

Evaluation of Quality in Atlantic Salmon Angling

by

W. C. Hooper

Results of two sampling methods to evaluate Atlantic salmon angling quality are presented, compared and evaluated. One method involves data on angler catch-per-hour or per completed day collected by periodic field checks. The second method depends entirely upon a large random sample of the angling licencees to provide specific salmon and/or grilse catch per day data over the angling season. The field check method shows a relative decline in combined catch per hour of kelts and late bright-run salmon and grilse since 1965 but early bright-run angling quality has declined only slightly. The angling licencee method developed in 1969, appears to be a satisfactory method of assessing year to year catches, grilse-salmon compositions, angler distributions and overall angler success (catch-per-rod-day) for salmon rivers with sufficient annual angling pressures. A comparison of catch per-rod-day results of the field check method (completed trips) with those of the angling licencee method shows the latter method, where considerable non-resident angling occurs, to be a good indicator of weekly and seasonal angling quality.

THE INTERNATIONAL ATLANTIC SALMON FOUNDATION

QUARTERLY NEWSLETTER

Volume 2 (1) St. Andrews, N. B., Canada May 1972

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Offices

P. O. Box 429,
St. Andrews, N.B., Canada

425 Park Avenue,
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EDITORIAL

This edition of our newsletter was delayed so that we could report completely on recent developments in the salmon field. More has happened in the past six months of a significant and constructive nature than in the previous decade. In chronological order these events were:

December 1971 - President Nixon signed a bill authorizing import restrictions against foreign countries "conducting fishing operations in a manner or under circumstances which diminish the effectiveness of an international fishery conservation program."

- The United States and Canada issued a joint statement calling for an end to highseas fishing for Atlantic salmon.

February 1972 - Denmark and the United States announced a bilateral agreement whereby Denmark agreed to phase out of the "highseas salmon fishery" by 1976 and "to maintain the fishery for Atlantic salmon by local Greenland fishermen at approximately 1100 metric tons annually."

April 1972 - The Canadian government announced an immediate prohibition on the taking of Atlantic salmon by commerical fishermen over large areas (see page 5).

May 1972 - The Province of Quebec announced a commercial fishing ban for the entire Gaspe Peninsula, to come into effect immediately. In 1973, non bona fide salmon fishermen on the North Shore as far east as Sept Iles will not be issued permits.

- The United States introduced a resolution at the Annual Meeting of the International Commission for the Northwest Atlantic Fisheries (ICNAF) embodying the terms of the Danish-USA bilateral agreement. In a strongly worded statement, Canada opposed the resolution as offering "too little, too late", and submitted an amendment calling for total withdrawal from the highseas fishery by March 1, 1973. This amendment was not accepted in subsequent voting by delegates representing the 15 member countries of ICNAF. The United States proposal, seconded by Denmark, the United Kingdom and Norway, received the necessary majority for adoption.

While the result was obviously not completely satisfactory to Canada, it can be eloquently argued that the 1972 Danish-USA bilateral agreement represented a substantial breakthrough which should logically have been capitalized upon by subsequent ICNAF ratification. Nevertheless, the Canadian viewpoint that "the proposed phase-out if over too long a period (1972-1976) and the permissible inshore Greenland catch (1100 metric tons) is too high" should be viewed with complete objectivity. Canada does produce approximately 95% of the North American Atlantic salmon taken off Greenland.

In summary, we view recent events with satisfaction and believe that very substantial progress has been achieved toward the ultimate goal of total prohibition of the highseas fishing for Atlantic salmon and the recognition of preferential harvesting rights for coastal producing states.

Canada has recently taken some difficult but positive steps to safeguard the welfare of its Atlantic salmon and we were quick to congratulate Minister Davis on his courageous approach. Many other individuals and organizations in Canada, the United States and abroad have contributed to bring about a remarkable period of solid accomplishment. On behalf of Salmo salar we extend thanks and salute them all.

The United States and Canada have publicly stated that they intend to cooperate closely and be mutually helpful in future programs for restoration and rehabilitation of Atlantic salmon runs in North America. There could be no more propitious moment to begin than right now.

Jo. W. [illegible]

FISHERIES

Sunday Evening

"THE TRAINING OF NATURAL RESOURCE BIOLOGISTS"

Chairman: Walter Whitworth
University of Connecticut
Storres, Connecticut

"IMPLICATIONS OF A CHANGING ENVIRONMENT TO THE TRAINING OF NATURAL RESOURCE BIOLOGISTS"
A. W. Eipper
U. S. Bureau Sports Fisheries and Wildlife
Cornell University
Ithaca, New York

"DISCUSSION: PROBLEMS ASSOCIATED WITH THE TRAINING OF AQUATIC, NATURAL RESOURCE, BIOLOGISTS"
Leader: Richard Hatch
University of Maine
Orono, Maine

"DISCUSSION: CURRENT 'NATURAL RESOURCE, AQUATIC' RESEARCH AT UNIVERSITIES IN THE NORTHEAST DIVISION AMERICAN FISHERIES SOCIETY"
Leader: James McCann
University of Massachusetts
Amherst, Massachusetts

Film: "THE WAY OF A TROUT"

NED

Monday Evening

THREE CONCURRENT FISHERY SESSIONS

Session I: "ATLANTIC SALMON"

Chairman: D. Brent Lister
Resource and Development Branch
Department of The Environment of Canada
Halifax, Nova Scotia

"EFFECT OF VARIOUS HATCHERY REGIMES ON THE DEVELOPMENT AND MORTALITY OF ATLANTIC SALMON EGGS AND FRY"
T. G. Carey
Resource and Development Branch
Department of The Environment of Canada
Halifax, Nova Scotia

"ATLANTIC SALMON HATCHERY EVALUATION IN THE MARITIME PROVINCES"
J. A. Ritter
Resource and Development Branch
Department of The Environment of Canada
Halifax, Nova Scotia

"THE EFFECTS OF CORPS PROJECTS ON THE ENVIRONMENT IN THE NORTHEAST"
James Barnett
New York District Engineer
U. S. Army Corps of Engineers
New York, New York

"INFORMATION AND EDUCATION AS IT EFFECTS FISH AND WILDLIFE"
Harlan Brumstead
Department of Natural Resources
Cornell University
Ithaca, New York

Summarization: Herbert E. Doig
New York State Dept. of Environmental Conservation
Albany, New York

Society Business Meetings

<u>Tuesday Evening</u>

Hospitality Hour - 6:30 P.M.

Conference Banquet - 7:30 P.M.

<u>Wednesday Morning</u>

General Summary - 11:00 A.M.

Adjournment

ICNAF Adopts Danish Proposal for International Regulation of the Atlantic Salmon Fishery

Over ten years ago the inshore set net fishery for Atlantic salmon started off West Greenland. In 1960, the inshore fishery catch was 60 metric tons and since 1964 the annual inshore catch has averaged about 1,000 metric tons (1 metric ton = 2,204.6 lbs.). In 1965, offshore drift net fishing for Atlantic salmon began in the Davis Strait (off West Greenland), and each year between 1965 and 1969 the drift net catch has just about doubled. In 1969, the total catch off West Greenland was 2,144 metric tons, the inshore catch being 940 metric tons and the drift net catch being 1,204 metric tons.

Conservation organizations on both sides of the Atlantic Ocean are concerned because information compiled with respect to the Atlantic salmon raises serious question about the capability of the resource to sustain itself in face of possible overfishing on the high seas. Furthermore, these same organizations are deeply concerned because, in the high seas Atlantic salmon feeding areas, salmon stocks are inextricably intermingled. The stocks come from different spawning streams, different river systems, different nations, even different hemispheres.

High seas fishing takes indiscriminately from perhaps the very river runs needing particular protection and results in absolutely no rational or effective means of conserving basic stocks or ensuring adequate escapements for spawning. Proper management techniques require that harvesting of salmon takes place only inshore, at the mouths of streams or in the streams themselves. In this fashion adequate stocks can be maintained for each particular river run.

This is known to be the basic position held by the United States and other governments, by leading world biologists, conservationists, and commercial and sport fishermen.

In 1970, the International Commission for the Northwest Atlantic (ICNAF) adopted the following proposal for international regulation respecting the fishery for Atlantic salmon in the Convention area:

1. That each Contracting Government which has participated in the fishery for Atlantic salmon, *Salmo salar L.*, take appropriate action to limit the aggregate tonnage of vessels employed or catch taken by its nationals in the fishery in the Convention Area to a level not exceeding the aggregate tonnage of vessels so employed or catch so taken in 1969.
2. That Contracting Governments which have not accepted the prohibition on fishing for Atlantic salmon outside national fishery limits take appropriate action to prohibit fishing for Atlantic salmon outside national fishery limits in the Convention Area before 31 July and after 30 November.
3. That the use for salmon fishing of any trawl net, any monofilament net or any troll be prohibited throughout the Convention Area provided that Contracting Governments may authorize the continued use of monofilament nets acquired before 1 July 1970.
4. That these measures be in force for the year 1971 subject to review within that period, in the event of substantial changes in the catches of Atlantic salmon in the Convention Area or in home waters or in the fish stocks.

During the recently completed ICNAF Annual Meeting (June, 1971) in Halifax, Nova Scotia, Canada, the Commission rejected the Canadian proposal to "limit the aggregrate tonnage of vessels employed and catch taken by its nationals in the fishery in the Convention Area to a level not exceeding 80% of the aggregate tonnage of vessels so employed and catch so taken in 1969. . . ." The only nations voting in favor of this proposal were Canada, Spain, and the United States.

However, the Commission did adopt the Danish proposal to continue in force for the years 1972 and 1973 numbered paragraphs 1, 2 and 3 of the 1970 agreement (see above) which would be "subject to review within that period in the event of substantial changes in the catches of Atlantic salmon in the Convention Area or in home waters or in the fish stocks, or in the event of the entry into the fishery of states not at present participating." The only nations voting against the Danish proposal were Iceland, United States, and U.S.S.R., while Spain abstained from voting.

INTERNATIONAL ATLANTIC SALMON FOUNDATION

At the invitation of the Huntsman Marine Laboratory, the directors of IASF decided to establish the Foundation's Canadian headquarters at St. Andrews, N. B. St. Andrews has been an important center for research activities connected with the sea and fisheries for many years. The advent of the HML in 1970 provided the opportunity for universities and non-academic organizations to participate in a "cooperative venture in learning." Through its association with HML and the Fisheries Research Board of Canada Biological Station, IASF hopes to both contribute and participate in new programs of special importance to the rehabilitation of Atlantic salmon rivers in Canada and the Northeastern United States.

According to Wilfred M. Carter, IASF Executive Director, "The complex problem of reversing the present trend of events in the Atlantic salmon world is truly a 'cooperative venture,' and success will be attained only by moving forward rapidly in several areas, the most important ones being: (1) international agreement to limit catches, (2) progress in arresting environmental degradation, and (3) development of advanced management and research techniques."

During May 1971, IASF issued its first quarterly newsletter (Vol. 1, No. 1) consisting of nine pages. The aim of the newsletter is to circulate current news and comments of interest about the Atlantic salmon. Volume 1, No. 2, is scheduled to appear in August. Executive Director Carter states: "There is no charge to get on our mailing list, but a voluntary annual contribution to the Foundation would be a nice way of saying 'Thanks'." Financial contribution from U.S. residents should continue to be mailed to the IASF office at 425 Park Avenue, New York, N.Y. The IASF mailing address in Canada is c/o The Huntsman Marine Laboratory, P.O. Box 429, St. Andrews, New Brunswick.

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April, 1971

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646.	*Timothy L. Joyce Corvallis, OR	H. F. Horton
647.	Robert J. Rubelmann Arnold, MD	Office

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NEW LIBRARIES
March-April, 1971

21. The Curator
Marine Biological Research Station
Ratnagiri, India
22. Library
Korstic
I P O Box 1229
Seoul, Korea
23. St. Marys College of Md.
Periodicals Dept.
The Library
St. Marys City, MD 20686
24. Alabama Agricultural and Mechanical College
Library
Normal, AL 35762
25. Louisiana Wildlife & Fisheries Comm.
400 Royal St., Rm. 126
New Orleans, LA 70130
26. Rider College Library
2083 Lawrensville Rd.
Trenton, NJ
27. The University Librarian
Jawaharlal nehru Krishi
Vishwa Vidyalaya
Jabalpur 4, India
28. Miyazaki Univ.
Nogakubu Library
Funazuka-Machi
Miyazaki City, Japan
29. Alaska Dept. of Fish & Game
Commercial Fish Div.
Box 936
Seward, AK 99664
Attn: D. Hennick
30. James Cook Univ. No. Queensland
P.O. Box 999
Townsville, Queensland, Australia
31. NASA/MTF Technical Library
Mississippi Test Facility
Bay St. Louis, MS 39520
32. Service D Periodiques
Bibliotheque Centrale
Universite de Monteal
P.O. Box 6128
Montreal, P.Q., Canada
33. Gorham State College
Library
Gorham, ME 04038
34. Crane Co.
Rupert Lein
4100 S. Kedzie Ave.
Chicago, IL 60632
35. Kearney State College
Library—Serials
Kearney, NB 68847
36. Florida Tech. Univ. Library
P.O. Box 25000
Orlando, FL 32816
37. Wilmington College
Library
Wilmington, NC 28401
38. Imatran Voima Oy
Box 10138
Helsinki 10, Finland
39. Frederick W. Crumb Memorial Lib.
State University College
Potsdam, NY 13676
40. Superintendent, Nat'l Park
Dept. of Indian Affairs & No. Develop.
Box 518
Ucluelet, B.C., Canada
41. Univ. of Prince Edward Island
Library
Charlottetown, PEI, Canada
42. Liverpool Polytechnic
Library
Byrom St.
Liverpool 3, England
43. Serials Science Section
Science Library
McMaster Univ.
Hamilton, Ont., Canada
44. Biological Research Lab.
P.O. Box 640
Ann Arbor, MI 48105

(Numbering started September 1, 1970)

Stamp

THE INTERNATIONAL ATLANTIC SALMON FOUNDATION,

425 Park Avenue,

NEW YORK, N.Y. 10025

Att'n.: MR. FRANCES GOELET

THE INTERNATIONAL ATLANTIC SALMON FOUNDATION

July 1, 1972

AN INVITATION TO ASSIST ATLANTIC SALMON CONSERVATION

Since its founding in 1968, IASF has been actively involved in the promotion of wiser use of the Atlantic salmon and the enhancement of its natural habitat, particularly in North America.

Activities have included gathering and disseminating of factual information concerning the plight of salmon; sponsoring of meetings both with government officials and other voluntary conservation organizations to enlist support for constructive conservation reforms, including the elimination of excessive commercial salmon fisheries on the highseas and inshore; support for research programs to develop advanced management techniques for improving salmon populations, and assistance to individuals and groups wishing to advance knowledge of the Atlantic salmon either through education, workshops or publication of books and articles.

IASF has played a leading role in bringing about a recent period of solid conservation progress. Our objective is to reverse the historical trend which has been threatening the continued survival of Atlantic salmon, especially in North America. As important as anything else we have done is assistance provided to other groups which share our common purpose.

All of these programs depend upon the generous financial assistance of friends and benefactors. You too can help by becoming an IASF Associate, and by encouraging others to join us and share in our continuing conservation work for salmon and a healthier environment.

IASF is a research and educational organization. Contributions, gifts and bequests are tax-deductible in the U.S.A. under provisions of the Internal Revenue Code.

Sincerely.

W. M. Carter,
Executive-Director.

P.S. An addressed return envelope is enclosed for your convenience. If you are already on our mailing list as an IASF Associate, please pass this Newsletter on to an interested friend.

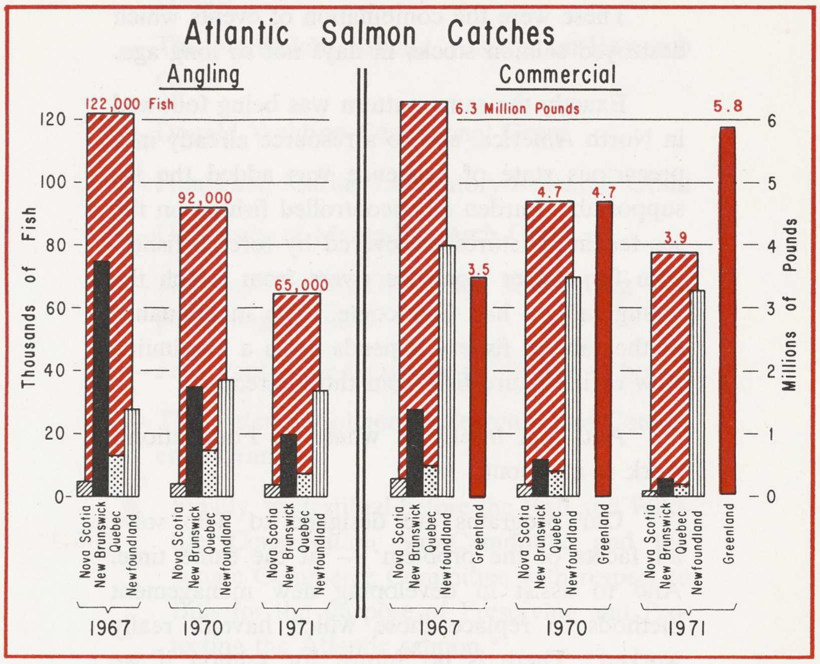
THE INTERNATIONAL ATLANTIC SALMON FOUNDATION
425 PARK AVENUE, NEW YORK, N.Y., U.S.A. — P.O. BOX 429, ST. ANDREWS, N.B., CANADA

STATEMENT OF PROGRESS 1971

- "We can see a useful role for our organization and we think that we can make a constructive contribution to the conservation and preservation of the Atlantic salmon.

  In cooperation with the Huntsman Marine Laboratory and other research, management and conservation organizations in the Northeastern States, the Maritime Provinces and Quebec we plan to expand and accelerate our involvement in Atlantic salmon conservation." IASF Annual Report, 1970.
- "This is the best fishery meeting I have ever attended."
- "This one publication will do more to further the cause of salmon restoration than anything now in print."
- "The Foundation was able in the brief space of two days to accomplish more for Atlantic salmon restoration in New England than has been accomplished in the past decade."
- "I am confident that the benefits from this Workshop will materialize in yet undisclosed ways that will affect the future course of salmon restoration and management in North America for many years to come."
- "Congratulations on a good job."

. . . Quotations from letters received following the IASF Atlantic Salmon Workshop in Manchester, New Hampshire, March 1971.



The involvement we referred to in our 1970 Report produced these gratifying results in one of our programs during 1971.

We hold the view in the Foundation that the approach to Atlantic Salmon management must be radically altered if we are to stop the continuing attrition of salmon stocks. The grave danger the continuing commercial fishery in the sea constitutes is but one cause of the current disaster.

Long before any high seas fishery existed, salmon stocks declined and in some instances disappeared entirely from well known streams in many countries, including the United States and parts of Canada.

If the historical record is even casually perused it can be readily seen that abuses perpetrated on the salmon were caused by man as he built his industrial civilization, damming streams for water storage and hydroelectric power; denuding forest cover vital to stream flow control; provoking erosion and silting to destroy natural spawning and eliminate areas where minute food organisms flourished; and finally to wilfully alter the chemical and physical properties of both the fresh and seawater environments by spilling agricultural and industrial wastes into waterways and the atmosphere.

Salmon surviving this desecration were then further abused by legally authorized but excessive fishing and by the poacher-thief in the night.

These were the combination of events which destroyed salmon stocks in days not so long ago.

Exactly the same pattern was being followed in North America, and to a resource already in a precarious state of existence was added the insupportable burden of uncontrolled fishing on the sea-feeding pastures discovered by foreign fishermen far distant from the rivers from which the young salmon had first come. The maintenance of the salmon fishery depends upon a continuing flow of immature fish from those streams.

And that briefly is what our Foundation's work is all about.

Our programs are designed to help solve all facets of the problem — at the same time. And to assist in developing new management methods to replace those which haven't really worked. There is no future for salmon if we succeed in controlling the offshore fishery but fail in efforts to eliminate other abusive practices nearer home. Failure to radically alter present management methods, and to resolve the difficult questions of resource ownership and unacceptable exploitation practices would constitute a mockery of fundamental conservation principals and nullify everything else we are attempting to do.

While on the one hand we are trying to encourage and promote fundamental change in the way which valuable Atlantic salmon resources should be managed and used, we are at the same time advancing new concepts of selective breeding, salmon farming and river restoration techniques essential to the future survival of Atlantic salmon.

1971 proved to be the most disastrous year for Atlantic salmon in recent history. Catches declined to all-time lows in many areas and more importantly, spawning escapement into North American river systems was reported below the numbers needed to maintain maximum population of young fish.

Dr. P. F. Elson, in a recent report entitled "Overfishing and Depleted Stocks of Northwest Miramichi Salmon", points eloquently to the serious state of salmon stocks there in his concluding paragraph.

"The salient fact is that Northwest Miramichi salmon populations are sadly depleted. They can no longer sustain the degree of exploitation to which they are now subjected. To assure recovery in the foreseeable future drastic curtailment of fishing is essential."

Meetings of the International Commission for Northwest Atlantic Fisheries produced a disappointing stalemate at Halifax in June. A Canadian resolution to further reduce salmon catches in international waters, strongly supported by the United States was defeated, while a Danish counter-proposal to maintain the fishery at present levels received majority support.

- Meanwhile the 1971 catch of Atlantic salmon in the Greenland area again reached the approximate 1970 level(4,721,200 pounds).

On the positive side are these encouraging developments:

- (1) Public sentiment is reflecting increasing concern over the present dangerous state of Atlantic salmon resources.
- (2) The Canadian government and the Provinces have at last moved strongly to reduce the impact of commercial fisheries.
- (3) Canada and the United States are coordinating their efforts to obtain a ban on the highseas fishery.
- (4) Volunteer organizations concerned with the conservation of Atlantic salmon in the United States and Canada have moved to focus their various programs more sharply by establishing the North American Atlantic Salmon Council.
- (5) The negotiating position of salmon producing countries has been strengthened by recent passage of a bill in the U.S. which authorizes the President to prohibit fish imports from countries whose fishing operations diminish the effectiveness of international conservation programs. *

1971 Program

In 1971 we expanded our activivties in many areas. These are some of the more important things we accomplished:

- Funding a feasibility study and design of a hatchery for breeding of Atlantic salmon to develop the most suitable strains of selectively reared salmon stocks for use both in the rehabilitation of natural salmon runs and for salmon farming in the Northeastern States and Canada. (Underwood, McLellan & Associates).

- Funding a study to evaluate available data and to assess the impact of present fisheries for Atlantic salmon in the sea on future survival of stocks in North America. (Dr. Jyri Paloheimo, Dr. Paul F. Elson).
- Embarked on a study of the role of international law in anadromous fish conservation and the preparation of a report for the Law of the Sea Conference. This report will develop new principles in international management and conservation of Atlantic salmon. (Dr. Wm. Mattox, Mr. Wm. MacKenzie).
- Completed the first successful Atlantic Salmon Workshop, at Manchester, New Hampshire.
- Prepared for an International Symposium on the Management of Atlantic Salmon to be held in St. Andrews, September 20-22, 1972. In this we are being joined by the Atlantic Salmon Research Trust, the Atlantic Salmon Association and the Miramichi Salmon Association.
- Started publication of a Quarterly Newsletter as part of a regular public information program. This Newsletter is sent to all IASF members.
- Sponsored the North American Atlantic Salmon Council. Founding members are: American Fisheries Society, Atlantic Salmon Association, Baie des Chaleurs Salmon Association, Conservation Foundation, Federation of Fly Fishermen, International Atlantic Salmon Foundation, Miramichi Salmon Association, National Wildlife Federation, Nova Scotia Salmon Association, Sport Fishery Research Foundation, Sport Fishing Institute, Trout Unlimited.

The Council's primary roles are to coordinate Atlantic salmon conservation programs of voluntary organizations, to eliminate duplication of effort, and to stimulate public involvement.

- In addition we have provided assistance through grants and awards for various projects relating to Atlantic salmon conservation.

To:

— The Atlantic Salmon Association-Conservation Award

— The Miramichi Salmon Association-Research Grant

— Donald Waldron-Educational Grant

— Huntsman Marine Laboratory-Research Grant

— University of Maine-Research Grant

— Anthony Netboy-Grant for researching and publishing of book

— Jean Paul Dubé-Grant for publishing of book

— The Atlantic Salmon Research Trust-Conference Grant

- Finally, we testified before the Fish and Wildlife Conservation Sub-Committee and the Senate Commerce Committee with respect to Bills for the Purpose of Preserving and Protecting the Atlantic salmon.*
- We are beginning a major article on the Atlantic salmon for international distribution and we are combining our efforts with other voluntary conservation organizations to prepare a documentary film on the Atlantic salmon.
- Through participation in various meetings, conferences, workshops and seminars we have used every available opportunity to advance the Atlantic salmon conservation movement ourselves, and to give all possible assistance to other organizations and individuals involved in the total effort in which we are engaged.

*(See Annex for the complete text of the IASF Statement to the Senate Commerce Committee).

1972 Activities

We are committed to continue our present programs and to develop new ones to expand knowledge of Atlantic salmon and to develop the techniques necessary for runs of Atlantic salmon to continue and to increase.

- We place the objective of rational international management of valuable Atlantic salmon resources ahead of everything else we are doing and our main thrust will continue in that direction.

- Specifically, we will participate in the Stockholm Conference on the Environment with the National Wildlife Federation; complete the Law of the Sea, the Selective Breeding-Genetics, and the Highseas Fishery Effect Projects.
- We expect to assist in the documentary film and we will have the International Symposium to host.
- Our Public Information activities will increase because this aspect of our work is responsible for stimulating interest, spreading knowledge and generating the funds we need to carry out the remainder of our programs. We intend to publish two issues of the IASF Special Publication Series and four numbers of the Quarterly Newsletter.
- We are providing the permanent Secretariat for the North American Atlantic Salmon Council and we will help that organization to coordinate programs of the various voluntary groups involved in Atlantic salmon conservation.
- New Programs will be developed to explore methods of Atlantic salmon farming and some pollution surveys will be undertaken on salmon rivers if sufficient funds are available.
- We expect to continue our programs of assistance to people and groups for education, re-reach and other important salmon conservation activities.

In Summary

In spite of the gravity of the present problem caused by the sharp decline in recent commercial and angling catches (in fact the 1971 catch was the lowest in 100 years in some areas) we are encouraged by highly positive signs. It appears that the seriousness of the Atlantic salmon situation has finally been recognized and signs of urgent activity to restore production and to limit abusive exploitation are apparent.

The International Atlantic Salmon Foundation has played a small but very important role in bringing this change about. Our involvement has been made possible by the generous contributions which have come in during the year from people who care in a number of countries, but principally from the United States. A substantial proportion of monies received by the Foundation in 1971 was contributed by Directors and friends. A generous gift from the John M. Olin Foundation enabled us to set up the Olin Educational Fund.

1971 also marked the tragic passing of three great men who had helped us from the beginning —Charles Engelhard, philanthropist, conservationist and one of our founding Directors; Dr. Börge Carlin, outstanding scientist and member of our Scientific Advisory Group; and W. J. M. Menzies, prominent salmon authority and member of our joint IASF/ASRT International Advisory Group.

Sir Hugh MacKenzie, Mr. Noel B. McLean and Mr. Dan W. Lufkin accepted invitations to join the Board of Directors. Mr. Knut Rom of Norway and Dr. Richard Vibert of France joined the other distinguished members of the IASF/ASRT International Advisory Group and the Scientific Advisory Group, respectively.

Successful completion of our programs each year is dependent upon the generous voluntary support we receive. To all who helped and contributed to our total conservation effort during 1971 we express sincere gratitude.

Board of Directors:

Anson McC. Beard	Noel B. McLean
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Hon. James Bonbright	J. Seward Johnson
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Sir Hugh MacKenzie	Robert Winthrop

Respectfully submitted,

W. M. Carter

Wilfred M. Carter
Executive Director

Gifts to the International Atlantic Salmon Foundation are tax deductible in the U.S.A. Contributions should be addressed to:

International Atlantic Salmon Foundation
425 Park Avenue, New York, N.Y. 10022
or P.O. Box 429, St. Andrews, N.B., Canada.

PRINTED IN CANADA

FISHING RESULTS

Our December Newsletter (Vol 1, No 3) carried details of salmon catches in 1971 for most areas. This additional information and early 1972 results recently released are now provided to complete a total picture of the Atlantic salmon fisheries.

GREENLAND

Provisional figures now indicate that the total Greenland catch in 1971 reached 2615 metric tons (5.8 million pounds). This represents a 24% increase over 1970 figures and is the highest catch ever recorded at Greenland.

IRELAND

Although final figures for Ireland are still not available, there are indications that catches of salmon and grilse in 1971 were higher as a whole than in 1970. Early 1972 catches were somewhat better than in the previous two years and it is expected that the final season catch will approach 176 metric tons for salmon and 1450 metric tons for grilse.

SCOTLAND

Provisional figures for 1971 indicate 149,268 salmon and 240,885 grilse were landed by all methods, a decrease from the 1970 catch of 174,070 salmon and 243,226 grilse.

The 1972 spring season followed the same pattern as 1971, with the appearance of fish well up the larger river systems on opening day. Good catches were to be had by anglers on the higher beats of the Aberdeenshire Dee, Tay, and Tweed with large fish being reported, including one of 36 pounds from the Spey. On one exceptional day, 46 fish were taken by 6 rods at Kelso Junction Pool on the Tweed.

Commercial netsmen reported good landings early in the season although catches were somewhat lower than usual in March due to bad weather.

As a side note, a firm rearing Atlantic salmon on the west coast of Scotland has now begun to market its fish at the going rate of $1.70 per pound.

NORWAY

Longline fishing outside the Norwegian fishery limit landed approximately 500 metric tons of salmon in 1971, compared to 1000 metric tons in 1970. The commercial catch within the fishery limits was 950 metric tons, about the same as the 1970 catch. River fishing in 1971 also remained at the 1970 level with a catch of 250 metric tons.

In overall assessment, the total catch (commercial and recreational) has decreased from 2300 metric tons in 1970 to only 1700 metric tons in 1971. This has not been very encouraging for the Norwegians who in recent years have made efforts to rebuild their salmon stocks through massive stocking programs and the opening of new salmon waters with the installation of more than 100 fish ladders.

ENGLAND AND WALES

Catches (metric tons)

Year	Rods	Nets	Total
1970	84	443	527
1971*	86	329	425

Total Salmon and Grilse Catches by Rod and Net (metric tons)

Year	Salmon	Grilse	Total
1970	313	214	527
1971*	298	127	425

*Provisional

North American Atlantic Salmon Council

MEETINGS

At the request of the North American Atlantic Salmon Council (NAASC), Canadian Fisheries Minister Jack Davis agreed to meet with Council representatives in Montreal on May 3 to discuss Canadian Atlantic salmon policy. This meeting was particularly timely in view of the Minister's announcement only a few days earlier of a ban on commercial salmon fishing over large areas of eastern Canada (see page 5).

The Montreal meeting was followed by a similar conference in Washington on May 12 where NAASC met with Assistant Secretary of the Interior Nathaniel Reed, State Department Coordinator of Ocean Affairs Donald L. McKernan and other key government officials to discuss various viewpoints on the Atlantic salmon issue.

Both meetings provided a rare opportunity for personal discussion of the many problems confronting the Atlantic salmon and assessment of the steps being taken to solve them. We hope that in the future NAASC, as an intermediary between government agencies and the conservation community, can provide a constructive service to the cause of Atlantic salmon conservation.

NAASC POLICY

The North American Atlantic Salmon Council was formed in December 1971 to provide organizations concerned with Atlantic salmon conservation with a means of pooling their resources and energies to achieve the following mutual objectives:

1. Presentation of a strong, united voice, on behalf of the conservation community, on all matters concerning Atlantic salmon.
2. International acceptance of the principle that salmon-producing countries shall have preferential rights concerning the conservation and use of Atlantic salmon.
3. Enhancement of Atlantic salmon populations through the development and use of sound management and environmental improvement programs.
4. Elimination of the Atlantic salmon fishery in international waters.
5. Improved utilization of the Atlantic salmon resource through applied research.
6. Continued dialogue and exchange of information between member organizations and the responsible government agencies.

The 15 member organizations are:

American Fisheries Society
The Atlantic Salmon Association
Baie des Chaleurs Salmon Association
Canadian Wildlife Federation
The Conservation Foundation
Federation of Fly Fishermen
The International Atlantic Salmon Foundation
The Izaak Walton League of America
The Miramichi Salmon Association
National Wildlife Federation
Nova Scotia Salmon Association
Sport Fishery Research Foundation
Sport Fishing Institute
Trout Unlimited
World Wildlife Fund

IASF is providing the Secretariat for NAASC and correspondence should be addressed to the NAASC Secretary, W. M. Carter, at P.O. Box 429, St. Andrews, N.B., Canada (tel. 506 529-3293).

ATLANTIC SALMON DIRECTORY

NAASC is preparing a directory of all Atlantic salmon programs in North America which it will make available to all interested individuals and organizations. It is hoped that this directory will improve communication between all involved researchers and eliminate needless duplication in a field that urgently requires effective and coordinated action. Copies will be available in July from the NAASC office.

CAPITOL COMMENTS

U.S.-DENMARK AGREEMENT

Following passage of Senate Bill 2191 last December (see page 2 and the December Newsletter), Denmark requested a meeting with the United States to discuss the Greenland area salmon fishery.

These discussions resulted in an agreement by Denmark to phase out of the highseas Atlantic salmon fishery by 1976, and to maintain the inshore catch level by local Greenland fishermen at 1100 metric tons annually (1375 metric tons were landed in 1971).

At the subsequent ICNAF meetings in May, a resolution embodying the terms of this agreement, and extending it to other countries fishing in the Greenland area was adopted. Catch quotas from 1972 through 1975 shall not exceed the limits shown below:

Highseas Catch in Million Pounds

	(1971)	1972	1973	1974	1975
Denmark	1.98	1.76	1.32	1.21	1.10
Norway	0.75	0.66	0.50	0.46	0.43
Others	- -	0.02	0.02	0.01	0.01
Total	2.73	2.44	1.84	1.68	1.54

The resolution includes a clause requesting all ICNAF member countries to adhere to the total salmon fishing ban on the highseas not later than January 1, 1976. Denmark and Norway, the principal fishing countries, have indicated that they would adhere to the proposed ban not later than that date.

CANADIAN BAN

On April 20, 1972, the Canadian Minister of Fisheries, the Honourable Jack Davis, announced an immediate and total ban on the taking of Atlantic salmon by commerical fishermen in the following areas:

1) New Brunswick drift net fishery (floating nets off the St. John and Miramichi river estuaries)
2) New Brunswick inshore fishery (nets attached to the shore)
3) Newfoundland drift net fishery (floating nets off Port aux Basques)

On May 26, the Province of Quebec announced the total prohibiton of commercial salmon fishing over the entire Gaspe Peninsula.

Areas not included in either ban are the following:

- Newfoundland and Labrador inshore fishery.
- In Quebec, the inshore fishery on the North Shore of the St. Lawrence to the eastern limit of the province.
- The entire province of Nova Scotia.

The Canadian government statement indicated that bona fide commerical fishermen would be fairly compensated for the loss of fishing privileges. The ban is to last at least five years and may be extended to cover additional areas not included in the present announcement. Reasons given for the exclusion of the Newfoundland and Labrador inshore fisheries are that they have not been seriously depleted by the Greenland catches. The Nova Scotia catch was considered too small for inclusion in the ban. In the light of available catch data, these reasons leave us somewhat sceptical and unconvinced

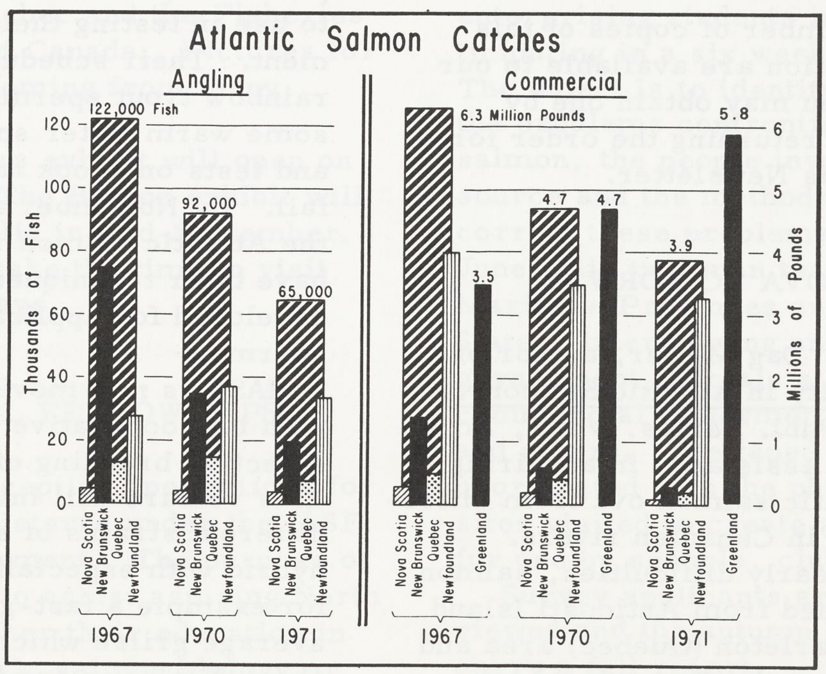
Pleas by commercial fishermen's organizations to expand the ban to include angling were rebutted by a statement to the effect that angling accounts for only 5-8% of the total Canadian catch, that it was of relatively major financial importance and that it had already been severely restricted by season and catch limitations.

This drastic medicine comes at a moment when it is sorely needed. Now that these essential restrictive measures have been enacted, and we trust will be enforced, there is justification for both government and private organizations to move on quickly with the massive job of restoring depleted runs and rehabilitating neglected Atlantic salmon rivers. There really wasn't much encouragement to tackle these things before.

N. B. ANGLING LEASES

On March 1, the Government of New Brunswick announced changes in its leasing policy respecting Crown waters under private lease. As of April 1, 1972, sixteen of the forty-one angling leases were converted to Crown Reserves, adding 242 miles of water to controlled public fishing. Of the discontinued leases affecting salmon waters, four were on the Miramichi, two on the Restiguoche, one on the Kedgewick, one on the Big Sevogle, one on the Cains and one on the Upsalquitch.

Remaining leases were auctioned off in Fredericton on March 27. The auction, held in the Legislature Building under the gavel of a Department of Natural Resources auctioneer, netted the province $127,000 in revenues for each of the next five years. The high bid on any section of water becomes its annual rental for the next four years, with an option for five more one-year leases at the same annual rate.



PROGRAMS IN PROGRESS

LAW STUDY COMPLETED

Volume 3, Number 1 of the Special Publication Series is now in print. The study, titled "The State-of-Origin as Guardian of Anadromous Fish: A Proposal", prepared by William MacKenzie for IASF, as a contribution toward the longterm solution to the problem of exploitation of anadromous fish, especially the Atlantic salmon. Copies of this publication are now being forwarded to governments, organizations and individuals with the hope that it will provide support for the thesis that anadromous fish should be under the management authority of their state-of-origin (the country in whose waters the fish spawn) during their entire life cycle. IASF believes that the Guardianship principle suggested by Mr. MacKenzie, or a modification of it, should be adopted at the 1973 Law of the Sea Conference in Geneva.

A limited number of copies of this Special Publication are available to our subscribers; you may obtain one by completing and returning the order form at the end of this Newsletter.

SALMON OVA TO NORWAY

In 1971, Dr. Dag Møller, author of Genetic Diversity in Atlantic Salmon... (IASF Special Publ. Series, Vol 1, No 1), asked IASF for assistance in acquiring fertilized Atlantic salmon ova from different populations in Canadian rivers.

After some early difficulties, salmon ova were obtained from Anticosti Island and from the Carleton (Quebec) area and were incubated at the Gaspe hatchery. From there, in February of this year, they went by air express to Bergen, Norway, and on to Dr. Møller's laboratories at the Institute of Marine Research.

Prior to the arrival of the Canadian salmon ova, Dr. Møller had already obtained samples from 55 different areas. He hopes to use the salmon derived from this collection for hybridization, selection, nutrition and behavior studies. IASF is anxious to cooperate in selective breeding programs for Atlantic salmon and is pleased to have played a part in Dr. Møller's work. We also wish to acknowledge the close cooperation and assistance of the Government of Quebec in obtaining the ova for this program.

SPERM FREEZING PROJECT

Dr. Robert Summers and Dr. Richard Gregory of the University of Maine have completed the acquisition of most of the equipment needed for their investigation into the effects of freezing on Atlantic salmon sperm. They have now begun to procure sperm from several fish species to use in testing their sophisticated equipment. Their schedule calls for tests on rainbow trout sperm this spring, tests on some warm water species over the summer and tests on brook trout sperm in early fall. By November and the beginning of the Atlantic salmon runs, they expect to have their techniques and procedures well developed for application to the salmon sperm.

IASF is now moving rapidly forward with its cooperative program for the selective breeding of Atlantic salmon. This venture will involve crossbreeding different strains of salmon to produce a hybrid with especially desireable traits, for example a fast-growing, larger than average grilse which would migrate only short distances and hence escape exploitation on the high seas. A frozen salmon sperm bank is essential to this selective breeding program and we are therefore delighted to aid Drs. Summers and Gregory.

AQUARIUM EXHIBITS

The New England Aquarium in Boston and the Huntsman Marine Laboratory Aquarium in St. Andrews will soon have live Atlantic salmon exhibits. In cooperation with these aquariums, IASF is preparing dramatic displays to tell the Atlantic salmon story to thousands of aquarium visitors each year.

When completed these exhibits will include a large tank of live adult Atlantic salmon, pictorial displays of the salmon's life cycle and the urgent problems encountered in maintaining and restoring this resource, and a taped commentary.

As part of IASF's public information program, the exhibits' purpose is to acquaint the general public with this endangered species and the threats to its survival. A wider awareness of the Atlantic salmon's problems, coupled with applied research, are the vital tools of Atlantic salmon conservation.

Live salmon for the exhibits are being provided through the courtesy of the Government of Quebec and the Fisheries Research Board of Canada. Pictures for the displays are coming from many sources.

The St. Andrews exhibit will open on or about July 1. The Boston exhibit will be open to the public in mid-September. We hope you will take the time to visit one of these displays.

EDUCATIONAL FELLOWSHIPS

IASF is now accepting applications for fellowships administered under the IASF Educational Endowment. The purpose of the endowment is to assist aspiring North Americans to further their education in the fields of Atlantic salmon biology or management or in related ecological areas.

The fellowships are valid at an accredited university, research laboratory or active management program anywhere in the world where specialized training in the Atlantic salmon resource is available. Applicants must be North American residents.

Current funding will allow annual fellowship disbursements of up to $3000, this amount to be divided among the successful applicants each year. Persons desiring information on application procedures should contact the IASF Executive Director at St. Andrews.

The IASF Educational Endowment has been made possible through a generous gift from the John M. Olin Foundation. We would like to see this educational fund, and the fellowships it makes possible, grow in the coming years and would welcome additional contributions (tax exempt) to this important program.

SUMMER SALMON SURVEY

A search is now underway for two enterprising students interested in participating in a six week "salmon survey". The object is to identify and photograph the problems confronting the Atlantic salmon, the people involved with the resource and the methods being used to correct these problems. Beginning in June, this two-man team will tour the Maritime Provinces and the Northeastern States, interviewing and photographing government officials at all levels, anglers, commercial fishermen, hatchery managers and others. The taped interviews will be coordinated with the photographs of the sites visited to create a slide presentation for use by schools, clubs and organizations.

Survey applicants are now being interviewed and the autumn Newsletter will carry a full report.

SYMPOSIUM NEWS

The final program for the September Symposium is now being printed and will soon be forwarded to all IASF subscribers. In the meantime here is some advance information.

Opening Proceedings will take place at the Algonquin Hotel in St. Andrews on the morning of September 20. A Keynote Address will be given by the Honourable Jack Davis, Minister of Fisheries for Canada. Later that morning the first Symposium session will be devoted to "The Effects of Man and a Changing Environment Upon the Atlantic Salmon". Luncheon will feature an address by Dr. D. A. Chant of the University of Toronto, who will speak on "The Values of Diversity". The afternoon session will focus on "Physiology".

Thursday, September 21, will begin with a session titled "Ecology", to be followed by a session on "Aquaculture". A Reception and Banquet will provide evening entertainment for the participants. The Guest Speaker at the Banquet will be the Honourable Adolph W. Schmidt Ambassador of the United States to Canada.

Friday, September 22, hosts a session on "Environmental Engineering and Fishery Economics" in the morning and the final Symposium session, on "Conservation and Fisheries" in the afternoon.

An impressive list of speakers, over twenty-five in all, will be presenting papers at the Symposium. Each is an authority in his field and will present the participants with pertinent, interesting, and often very new, information.

For those who will want to stretch their stay, a tour of Quebec and a tour of New Brunswick and Nova Scotia will be offered from September 23-28. Each tour will visit salmon installations and general points of interest. The final Symposium program will include more details.

As a reminder, the Symposium is open to all who wish to attend. We also hope that many of our guests will bring their wives to sit in on the sessions and/or to enjoy St. Andrews in September. A special ladies program is included in the Symposium arrangements. If you or your friends have not already registered to attend, do so now by completing the registration form on the final program or on the last page of this Newsletter.

All correspondence concerning Symposium registration should be directed to the attention of William MacKenzie at the IASF office in St. Andrews. Mr. MacKenzie will be staying with IASF until the end of September to assist with Symposium arrangements and the answering of inqueries received concerning Atlantic salmon conservation. He is author of the recently released publication, "The State-of-Origin as Guardian of Anadromous Fish: A Proposal", (IASF Special Publ. Series, Vol 3, No 1) and currently resides in St. Andrews.

SPECIAL VISIT

For a week in April, IASF was the host of Sir Hugh MacKenzie, Director of The Atlantic Salmon Research Trust, our Symposium co-sponsors. Although most of his visit was taken up with meetings to finalize Symposium arrangements, he did enjoy some IASF hospitality at the home of the Executive Director and at a dinner in his honor at the Huntsman Marine Laboratory.

His visit enabled us to better coordinate the activities of ASRT and IASF on Symposium matters, a job which is difficult by overseas mail. The final program is now completed; we are now looking forward to the Symposium itself.

REGISTRATION FORM

ATLANTIC SALMON SYMPOSIUM

Name ______________________________

Address ______________________________

____

Affiliation ______________________________

Title ______________________________

I will be accompanied by ______________________________

Please forward ____ copies of the Symposium Booklet
____ copies of the Maritimes Tour Brochure
____ copies of the Quebec Tour Brochure

Please register ____ (number of persons) for the Quebec Tour
____ (number of persons) for the Maritimes Tour

I will arrive (date) ____________ I will depart (date) ____________

Reserve accomodations at: The Algonquin Hotel ____ (Single ___) (Double ___)
H. M. L. Residence ____ (dorm).

Arrange transportation on September 19 from ________ Airport to
St. Andrews. I am arriving at ______ (time) on Flight _____.

I enclose $ ____________ in Canadian Funds for:

1. Registration Fee ____ (General $20, Ladies $12, Student $10)
2. Tour Deposit ____ ($35)
3. Banquet ____ ($10)
4. September 20 Luncheon ____ ($4)
5. H. M. L. Residence Accomodations ____ ($10 per night)

Make all checks and money orders payable in Canadian Funds to:
The International Atlantic Salmon Foundation

Return Registration to: IASF, P. O. Box 429, St. Andrews, N. B., Canada.

Of Special Interest

MEMBERSHIP CATEGORIES

IASF has recently instituted new membership categories. Contributors are now accorded the following titles:

Honorary Patron	($5000 or more)
Patron	($1000 - $5000)
Sponsor	($500 - $1000)
Associate	($100 - $500)
Fellow	($50 - $100)
Subscriber	($10 - $50)
Student	($5)

As in the past, all contributors will receive the Quarterly Newsletter and will receive issues of the Special Publication Series on request. Contributors of $100 or more will receive Special Publications as soon as they are available and will also from time to time receive special reports prepared by IASF. All contributions are tax deductible in the U.S.A.

MEETINGS

May 18 - June 4	International Commission for the Northwest Atlantic Fisheries. Washington, D. C.
June 5 - June 16	The United Nations Conference on the Human Environment. Stockholm, Sweden. Over 1500 delegates from United Nations member countries will meet to focus attention of governments and world public opinion on the urgent physical and social problems caused to the environment by technology, industrialization and population pressures. The conference is expected to result in the drafting of international agreements dealing with major environmental problems.
June 5 - June 16	An Environmental Forum. Stockholm, Sweden. Concurrent with the United Nations Conference. Held under the auspices of the Swedish United Nations Association and open to organizations and individuals concerned with the environment.
June 10 - June 12	Uniting Nations for Bio-Survival. Stockholm, Sweden. A symposium on world environmental problems conducted by the National Wildlife Federation, its purpose is to provide a forum for the expression of ideas on environmental problems by world Authorities and organized citizen interests. We are particularly pleased that the National Wildlife Federation has invited Wilfred Carter, IASF Executive Director, to be a speaker at this conference. Mr. Carter will present a paper on "The Atlantic Salmon - A Case of Man's Indifference to His Resource Blessings". He will share the podium with speakers on conservation topics covering worldwide interests.
September 20 - 22	Atlantic Salmon Symposium. St. Andrews, N.B., Canada.

PUBLICATIONS

LET'S SAVE OUR SALMON

Mr. Jean-Paul Dubé of Quebec has recently completed a book on the Atlantic salmon native to that area. Publication of Let's Save Our Salmon was assisted by a grant from IASF.

Published in both French and English, the book serves a dual purpose. In simple straightforward language the author notes the injustices to the Atlantic salmon which compromise its survival. He also relates how many of the problems that threaten this magnificent resource can, and should, be overcome. Mr. Dubé writes from personal knowledge of an area in which he has lived all his life and his book is recommended reading for anyone wishing to learn more about the Atlantic salmon in Quebec.

SALMON AND TROUT

We have been informed that Derek Mill's book, Salmon and Trout, reviewed in the December Newsletter, is also available in Canada. Readers interested in purchasing a copy should write to Clarke, Irwin & Co., 791 St. Clair Ave.W., Toronto 10, Ontario. The price is $16.

IASF PUBLICATION ORDER FORM

I would like to receive:

1. The IASF Brochure ___

2. Special Publication Series
   Vol 1, No 1 - Genetic Diversity in Atlantic Salmon... by D. Møller ___
   Vol 2, No 1 - Atlantic Salmon Workshop. ___ (enclose $4.75)
   Vol 3, No 1 - The State-of-Origin as Guardian... by W. MacKenzie ___

3. Quarterly Newsletter
   Vol 1, No 2 ___ Vol 1, No 3 ___ Additional copy this issue ___

4. IASF Annual Report: 1970 ____ 1971 _____

5. Genetics as a Tool for Intensive Management... (selective breeding plan) ___

6. Final program and registration form for Atlantic Salmon Symposium ___
   Tour Brochure - Quebec ___
   Tour Brochure - Maritimes ___

Complete and return to the IASF offices (address on reverse)

THE LAST PAGE

As this Newsletter indicates, recent events have given cause for increased optimisim on the fate of the Atlantic salmon. They should not, however, lull us into a sense of false complacency. There is still a great deal to be done. Since IASF was founded in 1968 we have become actively involved in a number of programs aimed at encouraging more rational harvesting procedures, stream restoration projects, genetics research, international fishery law analysis and other salmon oriented studies. All of this work continues to be important. In fact, with the phase out of the highseas fishery, the proper application of the information we have gained and shall continue to gain will be essential if the Atlantic salmon is to survive and prosper.

We know IASF can play an important part in the future of Atlantic salmon. But to play that part we need the support of all people who are concerned with the welfare of this resource. As the scope of our activities widens, our expenses increase. In fact, even to maintain our present program requires ever increasing financial commitments.

Last month we were pleasantly surprised to receive some contributions in honor of the birthday of one of our Directors. We felt this was an appropriate way to express tangible support for a worthwhile cause and to celebrate the birthday of an angling friend as well. Perhaps others may wish to follow this example. You need not, of course, wait for someone's birthday! Assistance in any amount at any time is most appreciated.

If you would like to join us in our work, the form below is for your convenience.

Name ______________________________

Address ______________________________

____

I enclose $________ as part of my contribution to the future of the Atlantic salmon.

I have a friend who would also like to help. Please send information on IASF to:

Name ______________________________

Address ______________________________

____

Clip and mail to: The International Atlantic Salmon Foundation

if mailed in USA: 425 Park Avenue,
New York, N.Y. 10022

if mailed in Canada: P. O. Box 429,
St. Andrews, N.B.

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ATLANTIC SALMON REVIEW

TASK FORCE FOR THE REVIEW

DEPARTMENT OF FISHERIES AND OCEANS

MARCH 1979

FOREWORD

Copies of this Review bearing the March 1979 date are of the draft having only federal and provincial inputs. The Review report is being made available to the interested public and the resource users to permit their appraisal of the adequacy and accuracy of the content. The Review will be placed in final form after giving due consideration to the comment and advice arising during the public consultation.

The Chairman

TASK FORCE MEMBERSHIP

Member	Subcommittee Subject	Affiliation
Jean Boulva	Administration of Fisheries Responsibility	Quebec Region
Yvon Côté	Administration of Fisheries Responsibility	Province of Quebec
R.E. Cutting, Chairman	Fisheries and Marine Service Costs	Maritimes Region
Clar Fisher	Socioeconomic Considerations	Newfoundland Region
R.W. Gray	Biological Conservation	Maritimes Region
J.H.C. Pippy, Regional Coordinator	International Factors	Newfoundland Region
J.D. Pratt	Resource Development	Ottawa Head-quarters
G.H. Rendell	Controlling the Harvest	Newfoundland Region
G.E. Turner, Regional Coordinator	Harvesting the Resource	Maritimes Region

FEBRUARY TO DECEMBER, 1978

CONTENTS

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[1]Due to the voluminous nature of several of these Appendices, and each one is a report in itself, it was not feasible to bind all these reports together. Limited numbers of the Appendix reports will be available for reference purposes.

INTRODUCTION

The Atlantic salmon is important among the fishes in rivers on Canada's Atlantic coast. Its presence impacts on the lives of many people in coastal communities and in inland communities in the five oceanside provinces. Moreover, even for those people without a close affiliation with the salmon, the species is often recognized as symbolic of success or failure in Man's protection of the aquatic environment within its geographic range.

Thus it is not surprising that deterioration of salmon stocks in the decades since 1930 has aroused widespread concern. Commercial catches dropped erratically from 6,100 tonnes in 1930 to about 1,800 tonnes in 1971. The anxiety was heightened in 1972 when the extraordinary measure of closing the commercial fishery and restricting the angling fishery in selected areas of New Brunswick was instituted in order to rebuild endangered stocks.

Governmental and private agencies and organizations have recognized the pressing need to review the status of the salmon to avoid re-development of another crisis if harvesting conditions are restored to those existing prior to the fishing restrictions. This concern is particularly acute in the Canada Department of Fisheries and Oceans, and the Honourable Romeo LeBlanc, Minister of Fisheries, asked that a review be undertaken. The purpose of this review is to collate available information on the salmon, determine problem areas, identify need for policy changes, and provide advice on those changes.

The Atlantic Salmon Review got underway in January 1978 with approval of the terms of reference and establishment of a Task Force of nine members. Each member led a sub-committee which was given responsibility for developing input to selected portions of the salmon knowledge sphere. Input from the subcommittees went to the Task Force, and the following report is the culmination of that review.

INFORMATION HIGHLIGHTS

The Atlantic salmon is indigenous to Canada's five easternmost provinces, where the resource is found in waters accessible from the sea. The resource base occurs in descending size in Newfoundland-Labrador, New Brunswick, Quebec, Nova Scotia, and Prince Edward Island.

Legislative responsibility for the salmon resource was granted to the federal government by the British North America Act of 1867. Subsequent interpretation of the BNA Act grants the provincial governments a proprietary right which allows the control of access to angling in non-tidal waters. An agreement between Quebec and the federal government in 1922 resulted in transfer of the administrative control for the Quebec salmon resource to that province. Salmon management responsibility in the other four Atlantic provinces is exercised by the federal government, as is total legislative responsibility.

The total annual production of salmon back to Canada would be about 775,000 multi-seawinter salmon (greater than 6 lbs: *large salmon*) and 755,000 1-seawinter salmon (less than 6 lbs: *grilse*), if spawning and rearing areas now accessible to the salmon were producing at their full potential. Such production would permit a domestic harvest of about 608,000 large salmon and 504,000 grilse, after Greenland exploitation and leaving sufficient spawning escapement for conservation. Available records indicate about 765,000 fish were harvested in 1977. The apparent under-harvest is caused by underproduction in some areas and by lack of catch reporting by some users and all poachers.

Salmon resource utilization is unique among Atlantic coast fisheries due to the sheer diversity of harvesting. The identifiable user groups are native people, anglers, and commercial fishermen. At this time, ten food fishery permits issued to Indian Reserve Bands are "operating" in Quebec (3) and New Brunswick (7), while food permits are issued to individual Inuits and Indians in Labrador.

About 6,875 commercial fishermen are eligible now for participation in the salmon fishery. Several hundred commercial fishermen capture salmon in fishing gear licensed for non-salmon species.

The quantification of salmon anglers is difficult because of the varying provincial systems for licensing anglers. About 60,800 residents old enough to require licensing were tallied in 1977. As well, 10,200 salmon angling licenses were issued to non-residents of the province of issue. Other recreational users, numbering some thousands, are those who are underage or who fish under the privilege of a family license.

Due to the harvesting pattern whereby large numbers of users capture the salmon, there is a chronic problem of incomplete records of catches. Even so, the ratio of angled fish to commercial fish, on a weight basis, has averaged about 1 to 11. The ease of marketing commercial salmon in private sale and the lack of requirement to declare either licensed commercial or angled fish catches have contributed to a passive attitude toward accurate catch records. The problem is compounded in some areas by the much too frequent capture of salmon in gear licensed for other species, wherein the salmon becomes a clandestine by-catch which is "always found dead" in the fishing gear. Poaching is a serious problem in some areas and is an unquantified drain on the stocks, being particularly devastating on the smaller stocks.

The West Greenland salmon fishery has affected Canadian stocks for nearly two decades. Strong circumstantial evidence suggests a considerable impact during the mid-1960 to mid-1970 period. Termination of the high seas drift net fishery and imposition of a 1,191-tonne quota for the inshore fishery has somewhat lessened the current impact on Canadian stocks. Negotiations are underway with the European Economic Community to complete an agreement in 1979 for continuation of a reduced quota when the present agreement terminates. However, a recent plebiscite in Greenland may result in Greenland assuming control of its natural resources outside the EEC, thereby invalidating any existing Canada-EEC salmon agreement for the Greenland fishery.

Some other form of agreement then will be required to hold the West Greenland drain on Canadian salmon stocks to a lowest level, presently averaging about 145,000 salmon per year.

Canada's salmon stocks are at various levels relative to their potential production. In general, those stocks most isolated from Man seem to be in best condition, such as those in Labrador. Stocks in New Brunswick and the Gaspé have benefited from the fishing restrictions implemented in 1971. However, the benefits would have been larger if exploitation in total had been held in check. Stocks in Nova Scotia are generally smaller ones and those could have benefited also from inclusion in the fishing restrictions. Large salmon have become scarce compared with past salmon runs in most Nova Scotia rivers, an effect also experienced in New Brunswick prior to the fishing restrictions.

Significant opportunities exist for increasing the production of salmon for fisheries in Canada's fishing waters. Stream inventory and stock assessment information on some 175 major river systems suggest an estimated additional 555,000 salmon can be produced using current technology. Much of the additional, self-sustaining Canadian salmon production potential lies in Newfoundland-Labrador. The still-experimental methods of semi-natural pond rearing and intensive "put, grow and take" fisheries could account for a further Canadian increase of 630,000 salmon. Thus, full-scale enhancement effort involving both self-sustaining and supported stocks could produce an additional 1,185,000 salmon, of which about 890,000 could be made available to fishermen, thereby increasing total Canadian annual production of salmon to about 2.7 million fish.

Additional production potential for about 130,000 salmon lies in the abutting international waters of the Saint John and St. Croix rivers, requiring coordinated programs with the U.S.A. before development proceeds.

Survey of opportunities for establishing Atlantic salmon commercial sea culture in eastern Canada indicates that the industry is developing slowly, largely because of limiting climatic factors. Adult brood holding, salmon production, and kelt reconditioning within sea cages could permit mariculture to play a role in restoration of salmon in various Atlantic watersheds.

The natural production of salmon is limited by environmental constraints, both natural and man-made, and by overexploitation of stocks. Some of the natural constraints, such as migration barriers, low-water productivity, excessive predation and species interactions can be overcome through installing fish passage at natural water falls, water fertilization, predator control and selective stocking programs. On the other hand, man-made constraints tend to be more serious and difficult to overcome, but technological measures do exist to improve the situation. A decline in Atlantic salmon stocks in certain areas has been due to environmental disruption caused by hydro development, forest spraying, tree harvesting and processing activities, agricultural activities, pollution from other industrial developments, stream alterations for flood control or road construction, and urban growth. While some of the salmon habitat lost because of environmental disruptions is not recoverable, proven enhancement and remedial measures could overcome these constraints in many circumstances and develop an additional 300 million square meters of salmon-rearing habitat.

Consideration of the salmon status would be incomplete without information on the current costs of stewardship of the resource. Expenditures during fiscal 1977/78 were about $1,555,000 for research and management including research ship time; $510,000 for habitat protection activities; $1,605,000 for enforcement activities including some catch statistics collection; $2,160,000 for salmon enhancement work; $51,000 for statistics tabulation; and $1,570,000 for compensation and license-buyback in connection with the commercial fishery; for a total of about 7.5 million dollars from regular federal operating funds in the Fisheries and Marine Service. Other federal special programs, such as students and Economic Growth Component, provided an estimated additional $450,000. The provinces of Newfoundland, Prince Edward Island, New Brunswick, and especially Quebec, were active in salmon-related activities, and their collective estimated total expenditures exceeded 3 million dollars for that year. Thus, governments expended about 11 million dollars in carrying out salmon resource responsibilities.

Interest in the salmon by people and governments has resulted in the formation of about fifty committees, working groups, and associations. Many are related to fisheries management responsibilities, but the user groups also have many associations, some with a long history of salmon conservation involvement. Although the three levels (individual, provincial, and federal) have considerable opportunity for contact, there is a need for better communication between all interest levels.

ELABORATION OF PROBLEMS, OPPORTUNITIES AND POLICY NEEDS

The following sections discuss the critical salmon issues identified by the Review process.

Resource Status

Canada's present salmon resource is not as large as could be produced with optimal natural populations. This species faces heavy exploitation as a result of high demand, as a recreational element, as a food supplement for native people, and as an item of commerce. Because many of the stocks are not producing at their highest level and fishing pressures of various kinds are eroding the river escapements, few rivers are receiving adequate spawning escapements, especially in Quebec, New Brunswick, and Nova Scotia. Salmon stocks in Newfoundland-Labrador seem to be in reasonably good condition, but estimates of spawning escapements show a 15% shortage of large salmon and a 10% shortage of 1-sea-winter salmon. The status of individual stocks, however, in all Regions varies widely depending on the circumstances.

One notable change that has taken place over a time frame of several decades has been the apparent decrease in the size of the large salmon component in most stocks. The decreased numbers of large salmon may be a reflection of such factors as selective exploitation, changes in fishing patterns, changed river productivities, or a combination of these or other factors. Current opinion suggests this trend may be stopped or reversed by reducing the harvest of large salmon through adjustment of fishing strategies in order to increase proportionate parentage by these fish.

The exact status of many stocks is unknown because of an inadequate information base including lack of comprenensive river inventory information and certain other biological knowledge. In spite of considerable experience with salmon problems in recent decades, there is a strong need for improved techniques for predicting trends in salmon stock levels. Improved predictive modelling systems have evolved slowly because of the marginal quality of the available catch statistics, significant knowledge gaps on a variety of individual stocks, and an inability to identify the complex mechanisms reflecting changes in fisheries and ecosystems. Some other important research requirements include studies of stock identification techniques, mixed stock exploitation rates, river productivities, mixing on migration routes, and stock-recruitment relationships.

Review of the salmon fishing strategy is timely. Past fishing strategies have allegedly damaged the maintenance of self-sustaining stocks and stock components and, as well, have contributed to wide fluctuations in catches resulting in economic uncertainties. Rising demand for greater numbers of salmon can be met through a program of salmon enhancement. However, the fishing strategies should be reviewed and adjusted appropriately prior to the influx of salmon from such an enhancement program.

(Reference: Appendix B, p. 34-95).

Regulation Enforcement

Enforcement of salmon regulations has undergone change in the last twenty years. The role of the Fishery Officer has been modified by demands on his time for duties that have decreased time available for salmon regulation enforcement. Decreases in manpower have further eroded the time for this activity. More recently, assumption of the extended jurisdiction to 200 miles has necessitated the further reduction of time spent in inland or inshore areas.

Poaching continues to be a serious problem, no doubt, because of the many forms it can take, the potential number of participants, the limited resources for attacking the problem, and the undeclared additional income poaching can provide at some risk. Unfortunately, in some areas, it appears that poaching is a social evil, constituting a challenge to traditional authority. As a result, certain people are willing to direct considerable effort at illegal fishing methods. Undoubtedly improved access to rivers, easier availability of poaching materials, high market demand, and faster transportation have encouraged illegal activities among those with an inclination to operate outside the law.

The success with which our education system is able to develop a more proper respect for Canadian fish resources will have a future impact on requirements for enforcement staff. However, on the short-term and due to present circumstances, there is a requirement to increase effort in enforcement areas. Additional effort is needed to reduce the incidence of violations of the regulations protecting the salmon resource. As well, more staff and training are required to upgrade the activities in enforcing the existing adequate regulations for the protection of the salmon habitats and environment.

(Reference: Appendix B, p. 96-110; Appendix D, p. 47-48).

Licensing Policies

Access to the salmon harvest is achieved through a licensing and permit system. Indian food fisheries are allowed under permit, while most recreational and all commercial fishermen are issued licenses.

Licensing of the sport fishery is handled by the individual provinces. Limitation of the number of angling participants may now be warranted, although angling pressure can be influenced by regulations controlling access, method, season and creel limit. Some control of angler numbers eventually will be required in order to maintain quality of the angling experience. In keeping with the user-pay philosophy, consideration for increased license fees for greater financing of management and enhancement programs is timely. Angling license fees presently go into provincial coffers and therefore are used to support and enforce provincial licensing programs.

Licensing of the commercial users of the salmon resource is a federal role, except in Quebec, and users are licensed in the salmon fishery. These and others may be licensed in related fisheries, but the licenses do not specifically allow the capture of salmon in the latter. The salmon fishery was the first significant "limited entry" fishery on the Atlantic coast, a policy introduced in 1969 in Quebec and in 1971 in the other four provinces. Although some differences in application have occurred in different regions, the licensing restriction has, relative to 1971, reduced the number of moonlighters[1], reduced the total number of participants eligible for the fishery in Quebec and the Maritimes, and has not been successful in reducing the total amount of licensed gear in Newfoundland. The licensing policy has been only moderately effective in achieving its aims. Problems still remain, especially with respect to the Maritimes, including: determination of eligibility for re-entry of those licenses bought out in 1971, determination of moonlighter definition application where formerly eligible fishermen are now otherwise employed but who prefer to return to the fishery when it re-opens, and determination of the permissible number of licenses for a stabilized salmon fishery. To the fishermen, the present policy appears to be one of attrition to the point of disappearance, since no base level in size of the fishery has been identified. Importantly, no provision exists whereby young aspirants with genuine interest and capability for participation can be licensed, except for those people with inheritance rights. This circumstance results in a rising average age of the commercial fishermen, and no moderation of the trend is in sight.

(Reference: Appendix D, p. 1-15; Appendix E, p. 8-14).

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[1]In 1971, the moonlighter was defined as a person having 9 months or more of employment per year in other than the primary industries of fisheries, forestry and agriculture. In some areas, this definition has since been made more restrictive, now requiring employment of 12 months as a fisherman only in order to avoid being classed as a moonlighter.

Salmon By-Catch

The migratory habit of the salmon makes this species vulnerable to capture in many types of fishing gear, especially those types in near-shore waters. The capture of salmon in gear licensed principally for other species, called by-catch, is a problem to fishery managers whose responsibility it is to establish and enforce catch limitations. Although the extent of this problem cannot be defined explicitly (due to lack of good catch records), the most conservative estimates of by-catch show its significant levels.

Salmon by-catches occur widely, but are concentrated in some areas. As salmon stocks have slowly recovered during the commercial fishing ban, the by-catch problem has worsened. In Quebec's Gaspé area, where documentation is best, the 1977 by-catch was about one-third of the total annual catch as compared with no by-catch reported in 1971. In insular Newfoundland, a recent study indicated that at least 30% of the salmon landings was a by-catch, but recent regulations have reduced this figure. On Nova Scotia's mainland area, the apparent by-catch in 1977 neared 50% of the total salmon catch reported there. In Prince Edward Island, by-catch occurs but the intensity is not known.

Indications suggest that the by-catch in recent years has increased in some areas, and that the fishing effort has been increasing. Many "other species" gears are involved, including the herring and mackerel gill nets, mackerel drift nets, cod traps, groundfish gill nets, and multi-species traps. All these gears catch salmon, especially when modified or operated for purposeful selection. Recent changes in regulations for some of these gears have started to reduce by-catch in those types.

The occurrence of salmon by-catch is ominously important if the viability of a licensed salmon fishery is to be ensured in all areas. The "non-bona fide" commercial fishermen and salmon fishermen have had access to salmon by-catch due to the lack of restriction on issuance of licenses for other species. Especially in Nova Scotia, the relative importance of the licensed salmon fishery is waning. This issue is important to the economists and those interested in distribution of the benefits from the salmon resource. Moreover, the managers of the fish stocks have an urgent requirement to document the actual total harvest, a problem made more difficult by the ill-defined by-catch.

The salmon by-catch problem is serious enough to warrant immediate action to reduce it, such as loss of suspension of licenses or changes in open season. Improved documentation would likely show even more clearly the by-catch importance relative to landings in the licensed salmon fishery. As well, it will confirm the inaccuracy of managing the fish stocks based only on incomplete catch records by the food fisheries, the sport fishery, and the licensed salmon fishery.

(Reference: Appendix B, p. 72, 75, 80, 83-85; Appendix E, p. 27-44).

Incomplete Records of Salmon Catches

The availability of thorough records of the salmon harvest is essential to effective management of the resource. Now, harvest records received from some angling, commercial, or Indian food fisheries in a number of areas can only be described as underestimates and non-existent. Angling or commercial catch estimates for most rivers are believed to be only approximate.

Non-declaration of salmon catches is not universal, but it is rampant enough to obscure the real catch totals. Some anglers apparently often do not wish to be identified, so angled fish are not reported. Of course pride and competitive spirit also influence angler behaviour about declaring catches, sometimes even at season's end. Commercial fishermen often market their salmon privately in order to obtain a better price and the income thereby derived can be undeclared for income tax purposes. As well, some commercial fishermen sell salmon to fish buyers only until qualification for unemployment benefits is reached and the remainder of the catch is diverted to private sales having a higher price. Surreptitious marketing of the salmon by-catch obviously has hidden the need for greater regulatory controls. Heretofore most Indian reserves have not declared accurate catches, apparently in an effort to avoid the appearance as a major user or to appear independent of control.

In summary, many users of the salmon resource are, passively or purposely, through their catch disposal methods preventing the compilation of accurate records of salmon harvest. Systems must be found which take these human self-interests into account, but which still provide the harvest information so necessary to managers of the salmon resource. Introduction of logbooks and/or catch-tagging schemes may prove to be a useful solution.

(Reference: Appendix B, p. 119-122; Appendix E, p. 18-44).

Allocation of Harvest

The Atlantic salmon resource must be managed so that Canadians derive a high level of mixed benefits on a continuing basis. Those benefits can be said to include increased income, increased job opportunity, improved use of leisure time, sporting opportunity, aborginal rights, and a form of social welfare, among others.

There are three major identifiable user groups: the anglers, the commercial salmon fishermen, and the Indians and Inuits. One can also include certain "other-species" commercial fishermen and the marine and freshwater poachers as users, although the dimension of their total use is more obscure. During the four years preceding the commercial fishing ban (1968-1971), available records show that the ratio by total weight of salmon taken by anglers and by commercial fishermen (all types) was 1 to 11. This ratio varies widely by province and by areas within provinces. Subsequent initiation of Indian food fisheries added a new user, but in 1977 these latter fisheries probably took less than 10% of the recorded Canadian salmon angling catch. In 1978, the Indian food fisheries took a greater proportion, as a result of reduced angling catches and a greatly increased catch at the Cross Point Reserve, Restigouche.

Present policy seems to rank the uses of the salmon, in decreasing priority, in this order:

1. Adequate spawning escapement for conservation

2. Native people food fisheries (when and where rights are recognized)

3. Anglers and commercial salmon fishermen

4. By-catch by other-species commercial fishermen

Effective salmon stock management absolutely must ensure fish for spawning. Also, efficient renewable resource management would seem to require strong effort to limit the by-catch in other fisheries and to eliminate poaching, a real, but unidentifiable, additional salmon user. Further, the food fisheries should be controlled so that the consumption is within the amount permitted by the definition of that food fishery.

There is at present a lack of policy for a percent allocation to the user groups, and one is sorely needed. As well, a policy on allocation of harvest to commercial fisheries in waters distant from the home river system must be established, including provision for the Greenland harvest.

The balance between the angling and commercial salmon users is one on which it is difficult to reach consensus because of the emotionally-charged subjective judgements subject to the political processes. Good information on socio-economic aspects, such as use valuations, community dependance, and income importance, would provide an improved basis for decision making. The availability of such information will assist both managers and users to understand the complexities for achieving the most benefits and the best distribution of those benefits.

(Reference: Appendix B, p. 135-142; Appendix E, p. 44-48; Appendix H).

Harvest Outside Home Waters

The Atlantic salmon is known for the range of its marine migrations. As a consequence of this behaviour, fishing exploitation can occur distant from the home river, from the province, or from the national fishing zones. Home river is defined as that fresh water from which the young salmon departed to undertake the marine migration, and home waters are the home river plus adjacent coastal waters.

Degree of harvest by fishing gear in distant waters is affected by individual stock characteristics including migration timing relative to the distant fishing effort, migratory route variation, and age at maturity. As a general rule, stocks migrating farthest from the home river or maturing at older ages experience the heaviest exploitation in distant waters.

Current evidence points to harvest of Canadian stocks in Greenland and St. Pierre-Miquelon, and U.S. stocks in Canadian fisheries. Domestic fishing patterns show harvest of Bay of Fundy stocks in the Atlantic coastal areas of Nova Scotia, Quebec north shore stocks in Labrador, Labrador stocks in eastern Newfoundland, mainland stocks in some areas of insular Newfoundland, western Newfoundland stocks along the Newfoundland south coast, Gaspé stocks off Miramichi Bay, north mainland Nova Scotia stocks along Cape Breton Island, and, probably, northern New Brunswick and Gaspé stocks in Prince Edward Island.

The capture of Canadian salmon in the West Greenland fishery is a burden that Canadian stocks and fisheries will have to bear in some measure for the foreseeable future. Suitable international negotiations must be renewed and continued in order to keep in force agreements which limit undue exploitation of Canadian stocks at Greenland and off St. Pierre and Miquelon.

The harvest of salmon produced in one area of Canada by commercial fisheries in another area is a concept requiring immediate review and appropriate clarification. If the present harvesting pattern were to be modified so that more salmon are harvested closer to their rivers of origin, considerable adjustment to present fishing methods will be required in some places. Such adjustments could have positive and negative effects on the conservation of salmon stocks and on socio-political aspects of the resource users. Thus, development of a harvesting plan for the future must take into account pertinent biological and socio-economic considerations, for which certain present baseline information is scanty.

Continuation of the present general pattern of the commercial fishery may not maximize the mixed benefits to Canada. Moreover, it is certain that salmon exploitation strictly in home waters is a near impossible goal, because fishing gears for other fish species must be operated at times when and where salmon should not be exploited. Incomplete detailed biological information relating marine migration patterns and timing of runs and a lack of adequate socio-economic information tends to support, at least on the short term, the continued operation of some mixed stock fisheries until sufficient information can be attained to permit assessment of alternatives. However, imposition of total allowable catches or quotas based on the production potential of specific coastal areas or management zones may be a reasonable interim alternative. Any future harvesting plan or strategy must take into account a number of socio-economic considerations before re-allocation from distant fisheries to home fisheries can be implemented. It is not yet certain that a salmon fishery based primarily on fish from distant river systems is biologically, socially, and economically the best approach for Atlantic Canada as a whole. However, there is substantial opinion and support that the long-term plan should strive to minimize commercial harvesting of salmon stocks produced in other management zones, even if total benefits to Canada are somewhat lessened.

(Reference: Appendix B, p. 88-92, 130-132; Appendix E, p. 49-52).

Native People Food Fishery

Food fisheries by native people of coastal Labrador have operated for some time. As well, the Inuit (Eskimo) of northern Labrador have long fished for food under permit in marine and fresh waters for salmon, char, and sea-trout, though the char is the most-utilized species. In southern Labrador, Indians under permit fish primarily for sea-run brook trout in marine and fresh waters.

In 1972, food fisheries at Cross Point and Maria were initiated at Indian Reserves along the southern Gaspé area of Quebec. These operations are directed at the Atlantic salmon, as is the north shore Natashquan food fishery that started in 1977. In 1974 the first food fishing permits for Indian Bands were issued in New Brunswick, upon cancellation of commercial salmon licenses for individual Indians. The seven New Brunswick Indian food fishing permits allow the setting of 52 nets, and the fishing effort for six of the permits is directed at the salmon.

Control of the food fisheries is attempted through conditions written into each permit, including quota (in Quebec) and season with gear limitations (in New Brunswick). Control has so far been inadequate in New Brunswick and Quebec according to allegations from other resource users. Moreover, to date, most of the permit holders have been uncooperative in providing accurate records of the salmon catch taken under authority of the permits.

If it can be assumed that food fishing permits will continue to be issued, certain critical matters should be resolved. A clear definition of "food fishery" must be delineated. Or, stated differently, what annual quantity of what fishes is each native person entitled to have, and can those fish be sold if the native person does not wish to consume them? And, will the food fisheries continue to be restricted to waters adjacent to Reserves having year-round residence? Several additional aspects need clarification including defining traditional fisheries and methods, catches for days of special celebration, and sharing of the catch among all Band members.

(Reference: Appendix B, p. 73, 77, 81, 85, 139; Appendix D, p. 18-22, Appendix E, p. 16-17).

Development of a Larger Resource

A bio-engineering review of the rivers in eastern Canada shows significant opportunity to increase the salmon resource base. Application of proven technical approaches in salmon enhancement would generate substantial economic, social and aesthetic benefits through fishery expansion by increased income, greater employment, and regional development. These enhancement techniques include hatchery smolt stocking, liberation of swim-up fry, adult transplants, and fish pass and stream clearance methods. Additional promising development and supportive techniques are emerging from applied research and pilot operations, the currently most important being disease immunization and control, innovative fish passage design, kelt re-conditioning, selective stock breeding and semi-natural rearing.

A comprehensive Atlantic salmon development program incorporating this technology would restore formerly productive river areas and colonize new stream habitat in eastern Canada. In certain natural ponds, the potential exists for substantial additional salmon smolt production. As well, a program using hatchery-reared smolts could support special localized intensive recreational and commercial fisheries. A hatchery stocking program could also be used to maintain ocean-ranching projects. Further, eastern Canada has an as-yet undefined potential for rearing salmon in sea-cage confinement, i.e., mariculture.

Major positive impacts of an enhanced resource would be the maximization and reduced fluctuation at a higher level of resource harvest by native food, commercial and recreational fisheries. The annual commercial catch in the Maritimes and Newfoundland commercial fisheries could rise by 2,250 tonnes (1977 catch was about 2,100 tonnes), which would increase and stabilize inshore fishermen's income by diversifying the marine inshore fishery. An increased sport creel would more adequately satisfy the growing strong demand by the economically important resident and non-resident recreational fishery.

All technical information and expertise must be used to ensure that salmon enhancement serves Canada's best interests. Analysis should now be undertaken to refine the feasibility and appropriateness of undertaking the salmon enhancement. A two- or three-year planning phase is required prior to commitment to a large-scale program. Detailed socio-economic evaluations respecting the alternative fishery harvest allocations to specific user groups and the generation of economic and other benefits, such as, native people programs, regional employment, and regional development, are required. During the planning phase, additional detailed biological and engineering information on project costing, scheduling and implementation must be developed to permit necessary benefit-cost analysis of projects. Special funding and manpower support are required for this detailed planning phase.

(Reference: Appendix B, p. 28-33; Appendix C, p. 74-78).

Communication with Resource Users

No fish species has as many committees, associations, and working groups considering its welfare than does the Atlantic salmon; no doubt because of its sporting appeal, the income it generates, and its multi-stock characteristic which provides local areas with "their own" stock. Nearly fifty of these groups have been identified.

This high level of interest and the constant need for updating information on individual salmon stocks have created a high demand for information and consultation. Enforcement aspects, shared provincially and federally except in Quebec, often have generated confusion in the minds of the resource users who aren't quite sure where responsibilities lie. Information exchange reference other provincial and federal activities is necessary to keep users aware of all salmon management programs.

Upon implementation of the commercial fishing ban and angling restrictions in 1972, Salmon Management Advisory Committees were established for three major river systems in New Brunswick – the Miramichi, Restigouche and Saint John rivers. The Committees provide advice to the Director-General of Fisheries and offer information exchange and discussion between anglers, commercial fishermen, and provincial and federal staffs, both biologists and enforcement officers. Although no one would claim perfection, considerable success has been achieved in providing communication between and with the resource users. Invitations to Indian Band Chiefs for participation in the Committees have so far received poor response.

In April, 1978, the International Atlantic Salmon Foundation hosted a New Brunswick Salmon Association Workshop for associations which represent nearly 7,000 members. One concern expressed at that workshop was the need for more information on the salmon. Importantly, the anglers also wanted more aggressive action by themselves in support of biologists and enforcement officers, and they proposed greater cooperation with commercial salmon fishermen in finding common bases for salmon management and harvest.

This example is typical of the opinions often expressed by resource users and fishery managers. More contact with more communication is necessary to generate better understanding and more cooperation in matters concerning the salmon resource.

(Reference: Appendix G, p. 29).

Environmental Quality Concerns

The Atlantic salmon is sensitive to many changes that can take place in its environment.

Canada's Atlantic coast drainages are the stronghold for Atlantic salmon in North America. Principally because of the moderate levels of urbanization and industrialization, the quantity and quality of salmon habitat has remained high in large areas of the region. Even more encouraging perhaps is the existence of extensive areas of potential habitat yet to be opened up to use by the species.

The five-province region has witnessed cases of the disappearance of Atlantic salmon or seen its existence seriously threatened because of habitat deterioration. Now, the same industrial, economic, and political pressures that have contributed to the demise of salmon habitat elsewhere in the species' North American range are becoming increasingly evident, even in remoter areas of Quebec and Newfoundland. Even though excellent regulatory and administrative mechanisms for the protection of salmon habitat are in place, the political, social and economic pressures still impact on enforcement of the environmental protection regulations. This effect is very evident at the present time in the Atlantic Provinces as a consequence of the existing economic climate. As jobs become scarce, more pressures are exerted to create industries even at the expense of environmental degradation, thus making habitat protection a never-ending task.

The success of habitat protection strategies will depend, in large measure, on the level of prevailing public consciousness regarding protection of the environment. Whereas habitat protection was at a peak in terms of public awareness and support in the late 1960's and early 1970's, some of the public may be less responsive to environmental adversities at present. Combined with present economic uncertainties, this may well signal the beginning of more difficult times in terms of habitat protection. It behooves managers to use the education/information approach as never before to counter-balance the political pressure for trade-offs. Just to maintain the existing quality and quantity of habitat over the next decade or so will require a supreme effort.

(Reference: Appendix B, p. 107-109, 113, 125).

RECOMMENDATIONS

The Atlantic Salmon Review has assessed many aspects relating to the salmon resource. The impending re-opening of the commercial salmon fishery in New Brunswick heightens the urgency for immediate new approaches and new plans for achieving and distributing benefits from the salmon resource. To that end, the Review has identified actions and recommendations in these aspects of total resource management, of which several will require funds and manpower for implementation:

I. Communication with Resource Users
II. Controlling the Harvest
III. Collection of Catch Statistics
IV. Need for Socio-Economic Information
V. Native People Food Fisheries
VI. Protection of the Resource and the Environment
VII. Mobilization for Enhancement
VIII. Scientific Information Needs
IX. Mobilization of International Initiatives
X. Promotion of Habitat Protection

Recommendations and pertinent discussion are grouped under these headings:

I. Communication with Resource Users

The existing multitude of committees, working groups, or associations confirms the strong need for communication between the general public, the users, and governments at all levels. The following actions would be helpful in expediting the communication.

A. Responsibility for Fisheries. Prepare a clear statement of the responsibilities of various governments with respect to Atlantic salmon.

B. Canadian Atlantic Salmon Committee. Establish an Atlantic Salmon Advisory Committee having representation from both federal and provincial governments and the resource users, preferably giving the Committee a permanent secretary. Representatives could be derived from regional hierarchial structures of advisory bodies, a structure which would vary, depending on regional requirements. For example, local river committees or advisory committees for designated management zones would report to a regional joint advisory body which would report to the Atlantic Salmon Advisory Committee, which would propose to or advise appropriate levels of government on solutions to problems. This communication system will provide increased opportunity for consultation with and by interested groups and agencies.

C. Communication Medium. Institute a newsletter or publication, possibly regional, which would periodically provide the users with information on current aspects of management and development of the salmon resource.

II. Controlling the Harvest

Atlantic salmon stocks, with few exceptions, are being harvested at the maximum allowable level and over-harvest of many stocks is already a reality. The high demand for salmon relative to the supply generates many conflicts in Canada's use of the resource. Specific and difficult actions are needed:

A. Effort Control.

(a) Prohibit any increase in total commercial salmon fishing effort. Transfers of effort between production areas or management zones can be permitted if conservation ideals are maintained.

(b) Stabilize native people food fisheries at an authorized level as soon as possible.

(c) Commence negotiations with the respective provinces to limit angling license sales to agreed levels.

(d) Each region should identify areas where over-fishing is occurring and take appropriate action to provide the minimum acceptable spawning requirement for each river.

(e) Seriously consider quota controls, especially if catch data collection methods can be improved and suitable control mechanisms developed for food, recreational and commercial fisheries.

(f) Establish a committee by May 1979, with appropriate socio-economic, enforcement, and biological representation to identify the number of commercial licenses which can be permitted in each production area or management zone and to determine mechanisms for adjusting participants to this objective.

B. Licensing.

(a) Continue the commercial salmon fishery as a restricted entry one.

(b) Implement a method to permit new entrants to the fishery in areas where the substitution of licenses will not cause excess exploitation, such as an entrance board of Fishery Officers and fishermen representatives.

(c) Institute a buyback plan for salmon licenses for select areas, such as in Nova Scotia, in order to bring the number of licenses in line with the available resource.

C. Allocation. Develop criteria for allocation of available harvest among legitimate users and user groups in accordance with regional differences. Criteria for allocation will be heavily dependent on an indepth socio-economic evaluation of the sharing fisheries.

D. By-Catch Control. Reduce by-catch, or salmon catch by commercial fishermen not specifically licensed to fish for salmon, by implementing regulations controlling seasons, gear, and fishing areas so as to minimize salmon by-catch to a practical lower limit. Determine accurate catch records for all salmon caught in non-salmon gear in order to document that by-catch which is impractical to prevent (See III(A), p. 17).

E. Mixed Stock Fisheries. Salmon stock management can be conducted most effectively on biological bases when harvesting is conducted in home rivers or in coastal waters close to the home river. However, on historical terms, Canada's salmon fisheries have developed under the considerable influence of social and economic factors. As a result, existing fisheries, especially in Nova Scotia and insular Newfoundland, are conducted as mixed stock fisheries. In view of the possible adverse social, economic, and political turmoil which could result in some areas by radical modification of present harvesting patterns so that fish (thus wealth) might be harvested closer to their rivers of origin, it is recommended that work on identifying stock compositions be expanded and evaluation of socio-economic aspects in areas of the most intense mixed stock fisheries be started. Following development of the biological management options and completion of the socio-economic evaluation of costs and factors, develop a program which will maximize net national social and economic returns from the salmon resource components. A current example is that work conducted by the Working Group on the Newfoundland Interception of Mainland Salmon. Now that much of the biological management work is complete, the complementary socio-economic evaluation must be finalized. Not only will completion establish a Fisheries and Marine Service base for decisions in this circumstance, but the case would serve as a pilot stage for understanding and/or expanding adjustments to a mixed stock fisheries in general.

III. Collection of Catch Statistics

The Atlantic Salmon Review has identified the growing demand for a diminishing salmon resource. To maximize the benefits from the resource, appropriate socio-economic evaluation information must be used. In order to obtain the socio-economic information, accurate catch and effort statistics must be available as foundation material. Certain inaccuracies or uncertainties exist in present catch statistics from most fisheries, but these are most acute in the sport fishery and the "by-catch" fishery. Several steps can be taken to cope with this problem:

A. Commercial Fishery. After consultation with commercial fishermen, begin enforcing Section 48 of the Fisheries Act, which requires declaration of catches, in those fisheries in which salmon are captured. To expedite the record transfer, institute a logbook system[1], probably beginning in the Maritimes Region. The Research and/or Resource Branches should provide standards for accuracy and completeness that have universal application.

B. Legalizing Capture of Grilse. Change the regulation to permit capture of grilse, where grilse cannot now be harvested legally by commercial fishermen, when increased escapement of large salmon can be ensured through reduced exploitation.

C. Recreational Fishery. Coordinate a federal-provincial approach to develop a system for accurate angling catch and effort levels. Seek cooperation from the salmon anglers to ensure broad support for improved records and develop appropriate legislation.

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[1]Implementation of a logbook system should be considered with reference to similar needs for other commercial species.

D. Single Record Source. Establish a single source for the official catch statistics in each region. The official set of statistics should be checked for accuracy and completeness by the primary users — fisheries biologists. The approved annual set of catch and effort statistics should be published in a regular consistent format. The catch statistics in Appendix E are the most accurate through to 1978.

IV. Socio-Economic Information Needs

The Atlantic Salmon Review has confirmed that socio-economic information should form a major element for future decisions, such as those involving harvesting patterns, licensing limitations, and enhancement projects. However, evaluation for the future status of the salmon fisheries requires intensive baseline studies emphasizing the economic and social impacts of these decisions on users. These baseline studies should address both inter-regional and intra-regional aspects of the fisheries. Such studies are required for the determination of future salmon management strategies and to measure the general economic and social milieu in which a salmon enhancement program might be further developed. The baseline studies are a first-stage approach in the overall salmon fisheries evaluation process; a second-stage would determine the socio-economic impacts of specific enhancement projects proposed within the constraints identified in the baseline studies. Progress requires these actions:

A. Terms of Reference. Establish an inter-regional committee to prepare by May, 1979, terms of reference for the socio-economic studies. Without limiting the scope of the terms of reference to be prepared, the studies should address at least the following general problem areas:

- Determination of "best use allocations" to specific user groups in the different regions in terms of economic and social benefits generated, as affecting national income, regional employment, regional development, and local management costs.

- Description and quantification of the economic and social impacts arising from retention or from modification of mixed stock fisheries patterns, according to available management options.

- Determination of socio-economic benefits accruing to user groups arising from management strategies based on self-contained intra-regional fishing zones or home water fisheries.

- Identification of inadequacies in existing continuing economic data bases and development of recommendations ensuring continuity of such data.

- Examination of departmental salmon programs and administration costs and evaluation of these in relation to benefits arising from these activities.

- Determination of feasibility, appropriateness, and economic guidelines for undertaking an enhancement program to increase Atlantic salmon production.

- Determination of the merit and role of cost recovery in the implementation of present and new salmon programs or projects, including specific recommendations.

B. Conduct of Socio-Economic Studies. Adequate funds must be made available for the studies which, for the most part, can be undertaken by consultants.

V. Native People Food Fisheries

The entry of native people to the user groups, particularly during the fishing restriction period, has caused great concern among the other users. Although the other users now apparently accept the concept of legitimate food fisheries, the specific legal entitlements and control measures for food fisheries are not yet in place. In order to integrate the food fisheries into salmon management strategies for harvesting, immediate actions are required:

A. Food Fishery Definition. Undertake appropriate consultations and negotiations to arrive at a fair, reasonable definition of a food fishery.

B. Legal Rights. Take immediate action to identify and define the legal entitlements of native people.

C. Enforcement Policy. Develop and make public principles in a policy for the control of native people food fisheries, just as controls for the other users are public information.

VI. Protection of the Resource and the Environment

Enforcement of the regulations for management of salmon stocks, particularly the control of poaching, and for protection of the environment is recognized as a vexing problem. Since many stocks are being used at maximum, or excessive, utilization rates, the impact of poaching is even more acute. The movement of available manpower from inland to near or offshore effort has aggravated the problem. These adjustments are needed:

A. Increased Manpower. Staff committed to enforcement work on salmon and on habitat protection activities should be increased twenty-five percent over the 1978 level. The guardian system in Newfoundland should be replaced by a warden system on a one-to-one basis, employing the wardens for at least eight months per year to discourage turnover among qualified staff (see the Maritimes Region system). Enforcement staff should be relieved of other activities which reduce the effective manhours available for regulation enforcement. Contracting out certain routine operations may prove possible to obtain best use of staff.

B. Increased Training. In each Region, enforcement staff, especially new officers, should receive classroom training prior to field assignment, such as that now being provided in the Maritimes Region. Topics should cover habitat protection aspects of regulation enforcement as well as those for salmon and other fisheries regulation. All staff, including seasonal wardens, should have the necessary training to maximize their effectiveness.

C. Mobile Teams. Enforcement teams experienced in Atlantic salmon regulation and problems should be organized; maintained as units; provided with the most modern, effective equipment to ensure maximum coverage and impact; and deployed in problem areas when required.

D. Equipment Need. Many areas are in need of upgrading of the miscellaneous equipment used in enforcement work. Provision of improved equipment, particularly that for land and water transportation and for radio communication, should be sought. Greater use of helicopter services must be considered, where feasible.

E. Provincial Coordination. Improve coordination of regulation enforcement activities with provincial enforcement staffs. This approach is being used effectively now in certain locations, demonstrating the value of more widespread joint operations or coordinated actions.

F. Identification of Catch. Investigate thoroughly the institution of an identification system for legally-caught fish in order to decrease ease of marketing illegal salmon and to provide a cross-check on catch statistics. Present opposition to such a system seems to arise from alleged high administration costs and from some user resistance which may be based on recognition that the system could be effective in reducing unreported legal catches. A tagging system, using coded tags, supported by a sales record system offers considerable promise. Study and recommendations should be undertaken by a federal-provincial committee having representation from the legal profession, enforcement, and users.

VII. Mobilization for Enhancement

In light of serious Atlantic salmon stock level deficiencies in Canada, enhancement could become a major strategy for the production of river-sustained or hatchery-dependent salmon stocks to support and stabilize fisheries. This approach would effectively restore many depleted stocks or establish new ones as an alternative to other management measures, such as prolonged fishery closures with payment of compensation, slow natural colonization, or piecemeal regulatory restrictions. A bio-engineering review of the rivers of eastern Canada has identified significant salmon development opportunities and defined proven technical approaches which could realize greatly increased salmon stocks. An expanded salmon resource would generate new economic, social, and aesthetic benefits through improved fisheries including increased income, employment, and regional development. Socio-economic assessments have shown strong market demand plus high user-dependance for this species in several areas of eastern Canada. Immediate steps should be taken to determine the appropriateness of a large-scale, long-term enhancement program.

A. Planning Phase. Acquire funding and man-years to initiate a two-year planning study to optimize economic and other benefits of the proposed program. The study phase should begin in late 1979 leading to possible full enhancement program implementation by April, 1982. In particular, socio-economic analysis should now address future fishery allocations to specific user groups and benefits accruing from an expanded recreational fishery. Benefit-cost considerations should be included as an essential part of an enhancement project priorization process. During planning, more detailed biological and engineering information/criteria on project costing, scheduling and implementation should be developed.

B. Program Coordination. Create an inter-regional coordinating unit to integrate program input from the Maritimes, Newfoundland, and Quebec areas which would develop: the national planning framework; the required federal, provincial and international agreements, such as future water use, habitat protection, joint enhancement ventures, and cost-recovery; and inter-agency negotiations on program financing.

C. Inter-Regional Technology Exchange. Improve the innovative quality for the proposed enhancement program through a series of inter-regional seminars to examine existing and potential enhancement technology, bio-engineering, and socio-economic evaluative tools in relation to geographic differences and similarities. Dialogue between regions should also continue so as to improve the existing data base on such aspects as enhancement production potentials, standardization of statistical formats, project planning criteria, and schedules.

VIII. Scientific Information Needs

Significant biological knowledge gaps exist in Canada pertaining to the scientific management of individual Atlantic salmon stocks, a shortage caused by the number and diversity of those stocks. Increased emphasis should be placed on biological investigations and research on wild salmon stocks. Such change, if effective, will require an increase in staff and a review of present programs for possible re-direction of existing staff.

A. Fisheries Management.

(a) Initiate a detailed stream inventory program to expand and update existing biological information on the quantity and quality of available salmon habitat.

(b) Expand the marine salmon programs, especially in the Maritimes Region to complement that in the Newfoundland Region, to study salmon migration routes, exploitation rates in the various fisheries, mixed stock vs individual stock harvesting strategies, and stock identification techniques throughout eastern Canada.

(c) Review and develop improved techniques to provide early detection of changes in salmon stock abundance. New predictive fish population modelling techniques should be explored which incorporate current biological data from on-going investigations, catch and effort data from fisheries exploiting particular stocks, environmental conditions affecting survival, and migration timing of salmon through the various fisheries. Rapid data processing should permit modification of fishing patterns during established fishing seasons, or to forecast stock strength annually or on a long-term basis.

(d) Divide the Maritimes and Newfoundland regions into management areas or zones where specific salmon stocks are studied and monitored annually.

(e) Initiate a review process immediately to evaluate all salmon enhancement techniques being utilized in the three Regions in order to develop the most efficient, cost-effective methods available for enhancing the salmon resource, including current fish culture programs and such promising techniques as large centralized upwelling boxes, stream-side incubators, adult transplants, artificial redds, kelt reconditioning, semi-natural or natural pond rearing, fertilization, and stocking various stages of juvenile salmon at prescribed densities.

B. Research. Research is required on more fundamental aspects of salmon biology, as demonstrated in individual stocks. The following study areas are particularly important:

(a) capacity of rivers for smolt production;

(b) biological characteristics of individual river stocks;

(c) adequate river spawning escapements or the required egg deposition levels;

(d) existence and impact of grilsification in salmon;

(e) biological significance of the composition of sea-age groups in spawning populations, the desirable proportions thereof, and methods for modifying the grilse:salmon ratio;

(f) level and variability of fecundity and sex ratios in representative populations;

(g) variation in survival rates during juvenile stages in representative stocks;

(h) utility of salmon sanctuaries in protecting wild broodstock for spawning;

(i) research on improved fish passage, particularly with respect to downstream fish passage, fishways in tidal locations, and cost-effective designs;

(j) minimum adequate river flow regimes where fish requirements conflict with other water uses;

(k) marine migration patterns and timing of at least the most important river stocks;

(l) fishing mortality estimates for commercial fisheries in different areas;

(m) fishing mortality estimates for recreational fisheries under varied river conditions;

(n) natural mortality rates in the sea at all size-classes;

(o) development of a model enabling prediction of spawning run and catch sizes prior to the beginning of annual fisheries.

C. Development of Fishing Plan. The importance of a long-term fishing plan or fishing strategy cannot be overstated. Such a fishing plan should be developed now with full realization that subsequent research and management information or socio-economic factors may require future modification of that plan. The purpose of the plan is to lay out the guidelines and fisheries management approaches on how to achieve the mix of benefits for Canadians from the available salmon resources as identified by activities under recommendation II(C), p. 16.

IX. Mobilization of International Initiatives

The Atlantic Salmon Review identified certain international considerations including fish disease threats, the potential for coordinated salmon enhancement activities, the potential for conflicting salmon enhancement activities, and harvest of stocks by other than the state of origin.

A. Fish Disease Threat. Reduce the risk of disease introduction into Canada or within Canada by promoting the development of self-sufficiency in each province with respect to seed stock for private aquaculture enterprises and government fish culture operations. Fish diseases, such as furunculosis, enteric redmouth, and whirling, present in Maine or other New England states, may spread to Canadian salmon stocks through straying or through stock transfer for aquaculture. In a high risk area such as the Bay of Fundy, a course of action must be planned should the disease introduction become reality. Diseases pose threats to wild salmon stocks in Canada and can be expected to cause severe losses in private or government fish culture operations. Furthermore, such diseases spread by salmon would surely transfer to other salmonid species such as the brook, brown, and rainbow trouts.

B. Coordinated Salmon Enhancement Projects. Canada and the U.S. share certain rivers having the potential for coordinated development of salmon stocks, these waters being the St. Croix and the upper Saint John rivers in New Brunswick and Quebec. Prior to salmon stock development, there must be a coordinated preparation of a detailed development plan delineating the responsibilities for each and all salmon restoration efforts in each country's sections and a utilization scheme for the available salmon harvests indicating the entitlement and users of the resources.

C. Conflicting Salmon Enhancement Projects. The U.S. and France are in a position to enhance salmon stocks which can become entangled in Canadian fisheries. If France were to enhance stocks on St. Pierre and Miquelon (no plans known at present), Canadian support of any such French effort should be withheld until agreement is reached regarding entitlement to enhanced stock harvests. The French-enhanced stocks will certainly intermingle with Canadian stocks along the Newfoundland coast and therefore be vulnerable to existing Canadian Fisheries there. Similarly, nets fished by residents of St. Pierre and Miquelon for their returning stocks would likely harvest some Canadian stocks migrating through French waters.

The U.S. is already engaged in salmon restoration and enhancement activities, and stocks are being harvested in certain Canadian fisheries in the Bay of Fundy, Nova Scotia, Newfoundland, and Labrador. The harvest of U.S. stocks is minor relative to the harvest of Canadian stocks at those times and places. The level of harvest of U.S. stocks may rise as more stock enhancement activity proceeds; but the proportionate harvest of the U.S. stocks by Canadian fisheries could decrease, if and when Canadian fisheries are changed, if the need is identified for modification of Canadian fisheries to maximize Canadian benefits from the Canadian salmon resources.

D. Harvest of Stocks by Other Than State of Origin. Canadian fisheries intercept U.S. stocks, and Canadian salmon stocks are intercepted by fisheries of other nations. Canadian salmon stocks contribute in a major way to the West Greenland fishery (approximately 40% of catch there), while Canadian fisheries harvest U.S. stocks at relatively minor levels. Canada's position with regard to intercepting fisheries is that salmon interceptions by states other than the state of origin should be minimized. Thus, these actions are warranted:

(a) Since existing demands by authorized user groups in Canada exceed the present salmon production and, probably, the potential for existing waters and enhanced stocks, Canada should, with regard to the West Greenland fishery:

- negotiate for a reduced harvest of North American salmon;

- oppose any changes in the fishing pattern proposed for the West Greenland fishery until a minimum two-year assessment of the proposed changes shows no increased harvest of Canadian stocks.

(b) Oppose expansion of the limited salmon fishery off the east coast of Greenland, in keeping with the principle of no new intercepting fisheries. Since tag return information shows North American salmon feeding there, the potential impact of an expanded fishery on Canadian stocks and fisheries must be assessed prior to increased fishing.

(c) Terminate the small annual fall salmon fishery on the east coast of insular Newfoundland to reduce the harvest in Newfoundland of those stocks primarily from Quebec and the Maritimes. This action will also affect favourably Canada's international image because it will reduce the harvest of those U.S. stocks present in the fall fishery.

X. Promotion of Habitat Protection

Habitat protection continues to be an important part of any plans to maintain or improve present Atlantic salmon stock levels. Past efforts have been significant in this area, but degradation of Atlantic salmon habitat has nevertheless continued at a persistent rate. Certain steps should be taken to reverse the trend and ensure an optimistic future.

A. Enforcement. Undertake a more rigorous implementation of pertinent sections of the Fisheries Act.

B. Federal-Provincial Cooperation. Promote and maintain close cooperation between federal and provincial agencies which have environmental protection responsibilities.

C. Education. Utilize an education/information approach to counterbalance any political pressure for environment trade-offs so that existing habitat will not be degraded.

D. Staff. Maintain staff assigned to protect the physical environment, both federally and provincially, at least at present level.

E. Training. Intensify training and education of existing inland surveillance officers to increase their technical competency in the area of enforcement and to demonstrate a will to enforce habitat protection regulations.

ACKNOWLEDGEMENT

The Atlantic Salmon Review was an immense task undertaken in an unreasonably short time frame. Any success or favourable results achieved as a result of conduct of the Review will reward the many staff members, both federal and provincial, who eagerly participated even while maintaining other regular duties. A "thank you" is token payment for the long, sometimes onerous hours spent assembling information. Positive actions leading to a greater salmon resource generating best benefits for Canadians will be the ideal legacy for the Atlantic Salmon Review.

Draft
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THE BIOLOGY AND USE OF ATLANTIC SALMON (SALMO SALAR LINNAEUS) IN CANADA--A SYNOPSIS OF PRESENT KNOWLEDGE AND ASSESSMENT OF RESEARCH NEEDS

By P.F. Elson and C.J. Kerswill

PREFACE (See 1970 version)

The main facts of the life history of Atlantic salmon (*Salmo salar* Linnaeus) have been recognized for more than three centuries. Because of the high esteem in which it is held as a food fish, because among anglers it is prized as the acme of freshwater trophies, and because the freshwaters and river basins necessary to its natural life cycle are increasingly exploited for other purposes by man's expanding industrialization, the search for knowledge pertinent to conservation and rational exploitation of the species has greatly accelerated in the last quarter of a century.

In Canada, concern about threatened extinction of Atlantic salmon stocks was expressed almost a century and a half ago, although even then there was some recognition of natural wide fluctuation in yearly abundance (Perley, 1849). Increasingly restrictive catch regulations were gradually introduced. In the last quarter of the nineteenth century Canada inaugurated what were for many years the largest artificial salmon rearing facilities in the world. In time it became clear to critical observers that current hatchery practices were not, in fact, yielding the anticipated augmentation of fisheries. About 1930 scientific research programs were initiated in Canada to learn more about the relations of salmon to the environment and factors affecting utilization of salmon in fisheries.

Atlantic salmon have been veiled in an aura of tradition and romance for two millennia. New facts not in accord with entrenched belief meet slow acceptance. Sport-fishermen, usually having more leisure and resources than those who harvest salmon for a livelihood, are particularly vociferous when seasons of scarcity strike. This age of increasing leisure, albeit increasing attrition of natural habitats to produce salmon, brings increasing demand to improve bases for scientific management of salmon. Reviews of current knowledge appropriately constitute an early step in recognition of areas for productive research.

In 1949 a "Resume of knowledge accumulated on Canadian Atlantic salmon ..." and proposals for research were prepared at the request of the then Assistant Deputy Minister of Fisheries. In 1950 new research programs were begun by the Fisheries Research Board. In 1952 Atlantic salmon research needs were again reviewed by the Board and the Department in a Co-ordinating Committee on Atlantic Salmon, which included provincial representatives; priorities were assigned and projects allotted to both the Department and the Board. In 1962, in the Annual Report of its St. Andrews Station, the Board presented a fresh review of accumulated knowledge on salmon, relating this to needs 10 years earlier. Most had been or were being met. Accomplishments and outlook for the future were summarized by Kerswill (1961). Since 1962 Research Board programs have involved completion of earlier projects and extension to some new areas involving basic studies in physiology, behaviour, and ecology, and increased emphasis on intrinsic (e.g. genetic) and extrinsic (e.g. environmental) factors associated with efficient utilization of Canadian salmon stocks by Canadians. From the early thirties to the mid fifties Canadian research efforts on Atlantic salmon ecology and production under natural conditions were among the most progressive. About 1950 several salmon-producing countries expanded programs for learning more about their salmon stocks. It was a period of increasing public demand for salmon in the face of a natural, temporary decline of stocks. Important recent steps towards recognizing research needs have included a review of Atlantic salmon literature by Pyefinch (1955); assembly of a bibliography on Atlantic salmon by Bergeron (1962); a review of Atlantic salmon knowledge by Dymond (1964); and finally, updating of Bergeron's bibliography was organized through FAO to include 1965 publications, and a bibliography on Baltic salmon was prepared by Carlin (1967). The last two are preliminary steps in assembly of an "Atlantic Salmon Synopsis" now in progress under FAO auspices and involving cooperation of ICES and ICNAF.

Canadian research on Atlantic salmon has included many useful contributions which have, for one reason or another, not yet found their way into print. This present synopsis endeavors to bring much of this product into sufficient light to permit its use as a foundation for future work, avoiding unnecessary repetition of effort. To fit these as yet largely unrecognized contributions, mostly from Investigators' Summaries of FRB, St. Andrews, Annual Reports, into a background of published literature, Dymond's (1964) review is used as a principal source and reference. Newfoundland Atlantic salmon researches have been covered largely through reference to Murray's (1967) review, "The Atlantic Salmon of Newfoundland".

In addition to the three Reviews of published scientific research on Atlantic salmon, numerous books have been written about the species, the latest being by Netboy (1968). Authors, naturally, tend to use a scheme of organization suited to their own purpose, although Dymond used a scheme similar to that of Pyefinch. The synoptic plan for "biological data on Atlantic salmon" suggested by the Inland European Fisheries Advisory Commission (EIFAC), under FAO, is another variant. Its rather general acceptance would have the advantage of bringing synopses on various species into somewhat uniform order. Its use, too, should have advantage for updating reviews in future more easily than if each involved an independent pattern of organization. Adaptation of the EIFAC synoptic framework to Atlantic salmon is not yet completed. The main skeleton can, however, be forecast to follow the outline given in our Table of Contents. It has been altered slightly to better adapt it for use on Atlantic salmon. Many references have been included, but in this draft by date of publication only. Organization will be completed later. (References given as 'SA 63/20' refer to Investigators' Summaries in FRB Station Annual Reports; SA = St. Andrews; SJ = St. John's; 63 = 1963; /20 = starts on page 20; AST = Atlantic Salmon and Trout investigations.)

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A SYNOPSIS OF SCIENTIFIC INFORMATION ABOUT ATLANTIC SALMON, WITH PARTICULAR REFERENCE TO RESEARCH RESULTS OF THE FISHERIES RESEARCH BOARD OF CANADA

1. Identity.

1.1, 1.2 Nomenclature and Taxonomy

Salmo salar Linnaeus; Atlantic salmon.

This synopsis deals primarily with typical sea-running populations of Atlantic salmon in Canada. Most readers will be familiar with the species. For descriptions and further discussion, reference can be made through Dymond (1964).

1.23 Subspecies. Present tendency is to include both sea-running and lake (landlocked) forms in the one species. Populations having their life history limited to freshwaters are sometimes given subspecific status, but no firm morphological evidence for subspecific groups has yet been reported (Wilder, 1947).

Of increasing interest recently is the possibility that the species may have racial variants recognizable more easily through behaviour patterns than morphology. This emerges partly from results of liberating hatchery-reared smolts of selected stock involving early- *versus* late-run and grilse *versus* large salmon parentage, though it has long been a popular belief. (See also 3.516; also 1.32, 1.33)

1.3 Morphology

1.31 For description of general morphology, proportional measurements, etc., refer to Dymond (1964).

Size varies from about 2 lb for small grilse to between 50 and 60 lb for salmon which have spent several years at sea before spawning. Large fish are apparently much scarcer today than 40 or 50 years ago. European salmon have been taken weighing about 85 lb, and perhaps up to 100 lb (Dymond, 1964). Average weights in Canada are about 3-5 lb for grilse, 9-12 lb for 2-sea-year salmon and 15-22 lb for 3-sea-year salmon. Dymond (*loc. cit.*) shows a length-weight curve based on records from several localities, both North American and European. Size for any given age appears to vary somewhat between stocks of different rivers and also from year to year. Hoar (1939) studied weight-length relationships of Margaree and Saint John adult salmon and Margaree young salmon. It is common among commercial salmon fishermen, especially, to hear the remark that fish originating from one river or another are distinguishable by their body proportions and/or fatness. Belding and Prefontaine (193) claimed to have defined such differences between Miramichi and Restigouche salmon. Martin (1949), using Hoar's salmon and other data, found that differences in body proportions do indeed occur. He found such differences often, if not always, attributable to differences in environmental conditions encountered near one or more of the inflections in growth rates (plotted on log-log relationship) associated with attainment of the eyed-egg stage, hatching, ossification, and maturity.

More data on size characteristics of different stocks are desirable and are now being sought by the Board and the Department's Resource Development Service.

1.32 Cytomorphology. Studies of chromosomes of Atlantic salmon began with Prokofieva (1934) and Svardson (1945), working on European, especially Baltic, salmon. Boothroyd (1959) studied three Canadian populations. He reported an average chromosome number of 2n = 56, compared to 2n = 60 for investigators of European salmon. Boothroyd concluded that, because of differences in chromosome shapes, the Canadian karyotype could be derived from the European. No clear-cut differences between the three Canadian populations were found.

Rees (1967) got a consistent count of 2n = 58 for Welsh salmon. He stated that a widespread, detailed survey is required to establish numerical polymorphism but believed the case for structural polymorphism (Svardson, 1945) is well established. Additional studies of chromosome patterns of carefully defined populations could add useful information.

1.33 Protein specificity. Within the last 2 years studies involving protein specificity of Atlantic salmon, using serological and electrophoretic techniques, have been initiated in both Europe and North America. Impetus has come from the need to distinguish North American from Canadian stocks contributing to the Greenland fishery. Because some types of protein specificity are linked to particular genes, the implications of these biochemical methods for distinguishing racial groups could have substantial impact on procedures of selective breeding for management. Studies on both sides of the Atlantic are still involved with finding productive approaches to the matter (Odense, unpub., 1968). FRB, St. Andrews, is commencing a program of this type in 1968.

2. Distribution

2.1 Total area

2.11 Geographic. There are spawning populations as far northwest as the George and Kosoak Rivers of eastern Ungava Bay and probably in the Leaf River on the western side of the bay. No salmon are reported from northern Labrador rivers southward to about Hopedale. But from the Hunt River, some 350 miles north of Belle Isle Strait, southward most rivers and streams of the Canadian Atlantic coast have salmon populations, provided they are physically suitable. Proceeding up the St. Lawrence estuary, salmon in sufficient numbers to support some angling frequent the Saguenay on the north shore and the Ouelle on the south shore some 70 miles below Quebec City (Dymond, 1964, and A.S.A. map, 1967).

In the ocean, a marked Canadian salmon has been taken as far south as Massachusetts (Huntsman, 194) and up to 30 years ago occasional catches of several thousand pounds were reported off Massachusetts shores. Occasional salmon have also been reported from trawler and hook-and-line catches on Browns Bank, and a Faeroese vessel (personal communication) reported taking 47 salmon in 1½ miles of drift-net on Georges Bank (Lat. about 42° N) in the spring of 1967; A.A. Blair (personal communication) has a number of similar records from the Grand Banks. Farther northward, recent recapture of salmon tagged as smolts shows that Maritime salmon may range into West Greenland waters (Saunders et al., 1964) at least as far as the Arctic Circle by the beginning of their second sea winter. An English fish tagged as a smolt has been taken at Latitude 73° N. Maritime fish at the beginning of their third sea summer have been taken along Labrador and Newfoundland shores (Kerswill, 1955). In 1968 research fishing yielded salmon well out in the Labrador Sea in March (Lat. about 55 to 60° N and Long. 51 to 57° W) (A.W. May, personal communication).

2.12 Biogeographical and natural characteristics. Within the ranges given above, salmon frequent most Canadian Atlantic streams down to quite small size (about 10 ft wide) and 1 cfs or less low summer flow, where physical and chemical conditions are suitable. Waterfalls over about 10-12 ft constitute barriers; chemical pollution may constitute barriers. Temperature should not exceed, in summer, about 25-28°C and Maritime streams with summer temperatures seldom rising above 10-12°C seem less favoured than warmer streams. Reproduction requires water-permeable gravel, fine to coarse, usually underlying at least moderate riffles, though such beds may be quite small (White, 1942). Excessively heavy rapids with gravel bottoms subject to constant molar action do not favour reproduction. For their early river life young salmon also favour areas of rather shallow, briskly moving water with gravel to cobble bottom, rather than deeper, slow stretches (Elson, 1967).

There is scant information about comparable limitations in the sea. Salmon have been taken at temperatures just below 2°C (unpub. data) and on their return to rivers may be taken, in salt water, at temperatures in the vicinity of 20°C (unpub. data). Possibly a combination of temperature, marine currents, availability of food, as well as other factors affect marine distribution. More research on this is needed.

2.2 Differential distribution

2.21 Spawn, larvae, juveniles (see, e.g., Jones, 1959). Salmon spawn is deposited in redds. Redds are usually located in areas of moderate flow over permeable gravel. They may be in any suitable location in freshwater reaches. A favoured but by no means invariable location is at the outflow of a pool where there is accelerating current. This assures circulation of water through the redd (Stuart, 1953).

The larvae, after hatching in spring in the redd, live in the gravel for some weeks, emerging into the upper layers of gravel substrate as the yolk sac is absorbed. After yolk sac absorption the young fish, though still living in close association with the substrate, may rise up into the water for feeding or other purposes. They may spread up- and downstream. White (193) gives something under ½ mile as the observed distance for spreading from one redd in a small stream. In larger streams Huntsman (193) has reported a diurnal onshore movement of young with approaching darkness. How and whether such movement affects territoriality (Elson, 1942; Keenleyside and Yamamoto, 1962) has not been examined. As the young fish grow larger they may occupy deeper water and even pools, but shallow reaches with stony bottom and rapid flow are the most important habitats throughout early freshwater life.

In winter many of the young seem to settle into interstices of the stony substrate. There is some indication that in streams with solid or compacted bottom lacking such winter quarters, many of the young drift downstream to more suitable habitat - or perhaps death. Study of wintering behaviour is needed.

2.22 Adults. Adult salmon in stream usually occupy comparatively deep pools when not travelling. Spawned-out adults which overwinter in rivers are reputed to occupy somewhat quieter pools than pre-spawning upward migrants. In some rivers early-run salmon ascend farther up rivers than do late-run (Saunders, 1967). In the Northwest Miramichi, from 1957 to 1963, 28,152 salmon and grilse passed through a counter 7 miles above tide head and 13,782 passed another counter about 40 miles farther up; 93% of the upriver fish passed before the end of August, when only 70% of the downriver fish had entered (Henderson et al., 1965).

Information on seasonal distribution of salmon in the marine phase is sketchy. Smolts leave rivers in spring frequently as river temperatures approach and exceed 10°C (Elson, 1967). They are sometimes reported from near-shore fisheries for herring, etc., during their first summer at sea (e.g., Comeau, 1909; SA 1963/20). Seasonal occurrence in Greenland and Labrador areas and other marine areas is mentioned in Section 2.12. Along the east coast of Newfoundland fish which will not enter rivers for several months are taken in winter. Most returning fish appear to reach home shores between May and October, but along the south Atlantic shore of Nova Scotia some have entered rivers (e.g., the Medway) as early as February and March; some enter the Saint John estuary in November and December but will not spawn for about 12 months (Dymond, 1964).

Most estimates of annual variation in abundance of salmon stock are based on commercial catch statistics (Section 5.43). Recent values were a low of a little over $1\frac{1}{2}$ million lb in the mid-fifties and a high of just over 6 million in 1967. Average annual landings for 1930-59 were 6.8 million lb. The last year of peak production was 1930 with 13 million lb (Kerswill, 1961). Catches about 1874, the recorded peak period, were only a little greater (about 10%).

Proportions of salmon and grilse in the run to a river may vary between years. From 1951 to 1955 the annual ratio of salmon to grilse entering the Northwest Miramichi was 1:2.5. Between 1963 and 1967 it was 1:19. Murray (1967) shows large variation in grilse:salmon ratios for Newfoundland angling catches between 1952 and 1966. Elson and Kerswill (1964) indicate similar variations in Miramichi angling catches.

2.3 Determinants of distribution changes (see also 2.2)

2.31 Effects of ecological determinants.

2.311 Nature of water flow and nature of gravel bottom help determine location of redds.

2.312 Summer water temperatures can be limiting for young salmon survival. For salmon parr acclimated to 20°C the 100-minute median lethal temperature limit is about 29.5°C, the 1000-minute limit is a little over 27°C (Alabaster, 1967). Most Maritime streams having such high temperatures probably provide suitable acclimation periods and except in some lake-fed streams such high daily maxima probably occur for mostly under 500 minutes. For smolts acclimated to 17°C, the corresponding lethal limits are about 27.5 and 25.5°C (Alabaster, *loc. cit.*). Again such limits probably seldom occur in Maritime streams during the late spring and early summer season of the natural smolt run.

For smolts moving abruptly from fresh to sea water, sea-water temperatures under 22°C have not been found to be lethal (Alabaster, loc. cit.). No natural sea temperatures as high as this have been reported for Maritime coastal areas during May or June, the normal season for smolt descent.

2.313 Exposure to light has been correlated positively with young salmon abundance in a stream where temperature was not a limiting factor (Elson, 1942a). This may have been associated with abundance of food organisms (Elson, 1942b). Effects of stream velocity and nature of substrate on distribution of young (Elson, 1942c, 1967) have been mentioned in Section 2.12.

2.314 We are not acquainted with systematic studies on turbidity or color of water and salmon. Adult salmon will enter rivers through extremely turbid estuaries, such as the Petitcodiac. They also ascend rivers during spates which frequently involve very turbid water. On the other hand, Huntsman (1945) found young salmon were displaced downstream during heavy spates, but does not suggest this was a result of excess turbidity rather than high water velocity. The natural low-water color of Canadian salmon rivers varies from crystal clear to very dark brown resulting from a burden of allochthonous material. While dark color may be related to basic productivity through limiting photosynthesis, sometimes reflecting a comparatively dystrophic condition of waters, it does not in itself seem to affect distribution of salmon.

2.315 Vegetation. Large aquatic vegetation is comparatively uncommon in most Canadian salmon streams. Huntsman (1952) suggested that decay of an unusually excessive growth of large rooted algae may have caused death of young salmon and other fish through oxygen depletion. But the excessive growth followed application of DDT at ½ lb/acre to the stream basin, as observed in other sprayed streams, and other factors may have contributed. In some streams rooted aquatic vegetation provides cover for parr.

2.316 Ice. St. Andrews investigations lead to a suspicion that excessive formation of frazil ice in streams may result in dislodgement of wintering parr, especially when the substrate lacks interstices for winter cover. Solid ice floating down-river has been reputed to cause egg mortality, especially when ice jams are formed on spawning gravels. Systematic research on how winter conditions limit salmon distribution is needed.

2.317 Pollution. Pollution by spraying insecticide over forest (Elson and Kerswill, 1967) and by copper and zinc (Sprague et al., 1965) limits distribution of young. Base metal pollution can also form a pollution barrier to upward migration of adults (Sprague and Saunders, 1967) as can pollution from some pulp mills (Sprague, personal communication).

2.32 Behaviouristic determinants. Young stream-living salmon occupy territories which they defend against intruders (e.g. Elson, 1942; Keenleyside and Yamamoto, 1962). The size and characteristics of suitable territories must set some limits to distribution. Scarcity of food (P.E.K. Symons, unpub.) can result in increase in the size of defended territories. Under ordinarily favourable conditions density of yearling and older parr is about 30 per 100 sq yd of stream bottom; but depending on habitat, food, etc., densities can be several times to only a fraction of the above (Elson, 1967).

Wintering behaviour (Section 2.316) may affect distribution of pre-smolt parr through mortality or downstream movement to more suitable habitat.

Distribution of salmon is greatly affected by the seaward and return migrations associated with normal life history (see Section 3.51).

2.4 Hybridization

There is, as far as known, little hybridization in Canada of _Salmo salar_ with other species. In Europe it sometimes crosses with _Salmo trutta_ (Jones, 1959). Work of Piggins (1964) in Ireland indicates the hybrids of these two species sometimes grow faster than either parent. Such hybrids might warrant research with a view to controlled rearing.

3. Bionomics and life history.

3.1 Reproduction

3.11 Sexuality and sexual dimorphism, etc. In common with other salmonids, Atlantic salmon show pronounced sexual dimorphism at spawning time. In males particularly, the snout and lower jaw become much elongated and a hook, or kype, develops at the end of the mandible; this fits into a hollow in the upper jaw. These changes are more pronounced in large fish.
Dr. Henry Heyl of Dartmouth Medical School (unpublished data) found this is associated with temporarily increased activity of the pituitary and perhaps other ductless glands. The teeth of mature salmon are reported to undergo change with approaching sexual maturity. The feeding teeth are replaced by shorter and broader breeding teeth which are in turn replaced by feeding teeth in those fish which survive spawning. The skin also thickens greatly with the approach of sexual maturity and scales become firmly imbedded (Dymond, loc. cit.). In actively growing smolts and fish in the marine feeding phase the scales are so loosely attached that almost any handling results in loss of a number of scales.

3.12 Maturity

3.121 Age. Atlantic salmon mature at various ages best defined as duration of the marine phase before maturity. Duration of river life seems to have little association with age at first maturity. Grilse mature after 1 sea winter at 2-6 lb weight. For larger salmon the most common sea age is 2 sea winters (about 8-12 lb), with 3 sea winters (15-20 lb) being not uncommon and 4 winters being rare. In Canada the scales of fish larger than about 20 or 25 lb usually indicate fish which have spawned at least once before.

The proportions of fish of different sea age in river runs vary from stream to stream and from year to year for a given stream (Section 2.3). Where grilse are a small component of the total run, they tend to be mostly males. Even when they constitute about two thirds of the run they may be two-thirds males (unpub. Northwest Miramichi data). But where nearly all the fish are grilse, sexes may be about evenly divided (unpub. Pollett data).

Male salmon parr frequently mature precociously. In a sample of 52 wild male parr over 7.5 cm long, collected for Margaree River studies in September 1965, 88% had enlarged gonads and shed milt when handled. Jones (1959) reported 75% of male parr became sexually mature during river life, and their sperm was as effective as that of larger fish in artificial fertilization. Male parr often participate, along with larger males, in the normal spawning act. Female parr are not known to mature.

Why salmon mature at different ages requires more investigation. Piggins (1964) found that there was some, but not universal, tendency to mature at the same age as parents. Recent experiments from St. Andrews have given similar results (SA'67/10). Since salmon of two different ages may spawn together, heterogeneity of genetic characteristics respecting age, if such exist, is to be expected. Participation of male parr in natural spawning would probably increase the chances for genetic heterogeneity.

3.122 Size at maturity. Covered above and in Section 1.311. Size at first sexual maturity varies from about 7.5 cm and 5 g weight for male parr, through about 45 cm and 1 kg for small grilse to about 100 cm and 10.5 kg for very large, usually female, salmon.

3.13 Mating.

Polygamy and promiscuity. Male salmon probably attend several females during the spawning season but are believed to attend fairly closely to one female while she is actively cutting and depositing. Even under these conditions, there may be competition among nearby males to fertilize any one emission of eggs. Male parr are frequently present and may shed milt at this time.

3.14 Fertilization is external. Jones found that in normal spawning there is very little wastage of eggs through failure of the eggs to stay in the bed. He also found that degree of fertilization from natural spawning in his tank studies exceeded 97%.

3.15 Gonads. Females vary somewhat in fecundity. Menzies (1925) gives a range of 500-1000 eggs per pound of female body weight. Canadian salmon are reported to have about 600-800 per pound of body weight. Dymond (*loc. cit.*) quoting Belding (1940) gives 834 eggs/lb for 10½-lb females, 723 for 19-lb females and 738 for 17-lb females that have spawned before. Pollett River female grilse (over 100 examined), average weight 4 3/4 lb, carried 800 eggs/lb of live body weight.

3.152 Most Atlantic salmon spawn once only. Some do recover to spawn again. The proportion which spawn more than once varies between rivers from about 5% to 30% or a bit more. About 10% of respawners appears to be common. In Restigouche angling catches, salmon over about 25 lb in weight are likely to be respawners. There is, however, limited information on the contribution of respawners in the salmon runs to many areas. Nor are the conditions which favour survival for repeated spawning known. Occasional salmon may spawn up to 6 times (Medcof and White, in preparation).

3.16 Spawning.

3.161 Atlantic salmon spawn only once in any given year, though the act of egg deposition for one female may be spread over several days or even a couple of weeks. Males can participate actively for several weeks, or while their supply of milt lasts.

3.162 Spawning season is in the autumn months in the Maritimes, usually October and November. In the Miramichi and southward it has begun by mid October, activity reaches a peak in late October and early November, is beginning to taper off by mid November, and is almost entirely over by December. However, in the Petitcodiac River of southern New Brunswick occasional fresh-run, mature fish have been observed in early December and one gravid female entered, upstream, a counting fence under several inches of ice in mid December. In northern Europe salmon may spawn in September or even earlier, while in southern England spawning has been observed as late as March (Dymond, loc. cit.). Spawning activity in streams of Ungava Bay (perhaps earlier) and southern Nova Scotia (perhaps later) may fall substantially outside the common October-November period for most of the Canadian Atlantic seaboard.

3.163 Time of day. Early in the season, and especially in clear water and small streams much, perhaps most, spawning activity takes place between dusk and dawn. But some activity on spawning beds can, under suitable conditions, be observed throughout daylight hours, especially as the season advances. Jones (1959) observed many spawning acts under sufficient light to permit photography.

3.164 Factors influencing spawning time. As noted in Section 3.162, spawning occurs earlier in high latitudes than more southerly: photoperiod may be a contributing factor, but is probably not a dominant one; streams in southern England with January spawning are substantially north of the Miramichi with October-November spawning. Run-off is important for river entry and ascent of streams; but Jones (1959) found even 20- and 30-lb salmon would spawn in appropriate water as little as 7 inches deep. This seems to leave water temperature as a probable controlling factor. In the Miramichi, in 1967, daily minimum water temperatures 7 miles above tide head first fell below 10 C on October 9; daily maxima fell below and remained below this on October 13. By mid November daily maxima occasionally exceeded 5 C but were mostly below 1 C. Spawning was well begun by mid October and largely completed by mid November.

3.165 Location and type of spawning ground. Salmon may spawn anywhere between tide head and headwaters, providing there are no barriers to movement and suitable spawning grounds occur

(Dymond, loc. cit.). They may occasionally spawn even in brackish water and produce viable eggs and fry (Saunders, 1966). There is an erroneous impression that salmon are essentially headwater spawners. While some, perhaps especially early-run stocks, reach headwaters, lower and middle reaches are often more important spawning and rearing areas, if only by reason of greater area.

Spawning grounds are stretches of permeable gravels, varying from fine (pea-size or a little larger) to quite large (many stones 4-8 inches in diameter). According to White (1942) an assortment of fine gravel, with even a little clean sand, to coarse stones is best. Spawning beds range in size from a couple of square yards to reaches several hundred yards, or more, long, and extending most of the width of the river (see also Section 2.2). Jones (loc. cit.) states that a depth of a few inches (e.g. 7 inches for 20-lb fish) will be used, and that most favourable water velocity is 12-18 inches per second at the surface: further he observed spawning would not take place with surface velocities as low as 2 or 3 inches per second.

3.166 Spawning grounds may shift to some extent as a result of natural instability of stream beds in the swift streams most frequented by salmon. Such shifting is generally more characteristic of upper, swifter flowing reaches than of the comparatively stabilized bottom of lowland reaches. One of us (Elson) has observed, with H.C. White, a situation where a log drive on a comparatively small stream, by loosening small, compacted gravels holding rooted aquatic vegetation, changed gravels previously unused by spawning salmon into productive spawning beds.

3.167 Ratio and distribution of sexes on spawning grounds. Ratio of males to females may vary from about 1:1 to 1:2 or possibly more with apparently little effect on level of natural reproduction (unpublished Pollett and Miramichi data). In streams with mixed salmon and grilse, the salmon, especially those entering early are often predominantly females, whereas the grilse are often predominantly males (see Hoar, 1939). Whether such mixed populations lead to an unbalance of sexes on spawning grounds is not known. The above observations arise from consideration of fish entering through counting fences. We do not know of any systematic studies of sex distribution on actual spawning grounds.

3.168 Nature of mating act. Jones' (loc. cit.) chapter on spawning of adults includes probably the most detailed available account of the spawning act. He summarizes the sequence of events thus: Cutting of the redd - first exploratory, then cutting of the actual nest by the female using her tail to create water currents which wash gravel away leaving a depression in the substrate. After the exploratory phase the male is usually in attendance. As the female completes formation of the pocket for the eggs, with its core of larger stones, she sinks her anal fin into the stones of the egg pocket, raising the forward part of her body. Deposition of eggs and fertilization - after opening her mouth in a gape, eggs are extruded. The initial crouch of the female and the gaping of her mouth are apparently signals to the attendant male. He slips alongside the female, heads about on a level, gapes and expands his opercula and with fins erect and body quivering squirts milt into the bottom of the redd. Normally ejection of eggs and milt are simultaneous. Covering of the eggs - immediately after the orgasm the female again cuts vigorously a few inches upstream of the egg pocket, the gravel now washed back covering the new-laid eggs. The new depression thus formed frequently serves as the beginning of a new egg pocket. Large females make deeper egg pockets than small, and deeper beds are also found in swifter-flowing water. The depression made by a 12-lb female may be a foot deep and her total spawning area may result in cutting up a length of about 16 ft of gravel.

3.169 Reproductive isolation. Mature Atlantic salmon show a high degree of homing to their natal stream (e.g. Jones, *loc. cit*.). In Miramichi experiments less than 1 in 1,000 adults marked as returning smolts were recorded as entering other than their natal stream (Kerswill, unpub.). The opinion has been expressed that some salmon even home to a particular reach of stream, perhaps where they grew as parr: White (1936) reports a tagged salmon found in successive years, each time occupying the same home pool. On the other hand, on the Pollett River where practically all descending smolts were fin-clipped, more unmarked than marked fish ascended through a new fishway over a dam a short distance below the marking fence and moved several miles on upriver (unpub. data).

As discussed by Jones (*loc. cit*.) use of upper versus lower portions of a river by early- versus late-run salmon could provide a degree of isolation. Saunders (1967) provides evidence that there was some such sorting among Northwest Miramichi grilse. From the same stream there is unpublished data showing a drastic decline in late-run, large salmon since pollution of the lower part, lethal to most parr, commenced in the mid fifties. First DDT affected the whole stream, then copper and zinc pollution removed most parr from the lower reaches from 1960 on. Both by local observation and by counting-fence records, the stock of 2-sea-year, late-run fish has almost disappeared. Since characteristics like early- versus late-running and maturation as grilse versus older fish affect utilization, there is clearly urgency to establish the respective roles of heredity and environment in producing such ecotypes.

3.17 Spawn.

3.171 External morphology. Dymond (loc. cit.) gives the diameter as 6-7 mm, Battle (1944) as 5.5-6 mm. Battle describes eggs and embryology in detail. Eggs are spherical, covered by a heavy, translucent, elastic chorion pierced by numerous canals. The bulk of the egg is composed of amber, semifluid colored yolk and a cap of pinkish orange oil globules. A thin cortical lamina of granular protoplasm covers the yolk but is more concentrated in one region, the blastodisk. After fertilization the blastodisk, now more prominent, rests on the oil cap.

3.2 Pre-adult phase.

3.21 Embryonic phase. The reader is referred to Battle (1944). Hayes (1930a, b; 1942) has studied metabolism of developing Atlantic salmon eggs, and the hatching mechanism.

3.211 General features of development of the embryo. The salmon is typical of the teleosts in its general development. Somite formation commences when the embryo is between 1 and 2 mm in length. After closure of the blastopore, at a length of about 4.5 mm (one fifth of hatching length) the embryo becomes progressively more fish-like. At a length of 6 mm, 60 somites, the adult number, are evident. Battle (1942) has described hepatogenesis in Salmo salar. Hoar described the development of the swim-bladder (1937) which becomes fully functional only after emergence from the redd, and the thyroid gland (1939) which,as the young fish later prepare for seaward migration, is is subject to active hyperplasia.

3.212 Rates of development and survival. Battle (1944), examining the rate of development in respect to temperature and thermal units (1 t.u. = 1 F above 32^{o} for a period of 24 hr), questioned the value of thermal units as criteria for determining stages of embryonic development. She found, however, that comparatively high temperatures at and just after fertilization and just prior to hatching did materially shorten the time for incubation. Dymond quotes Belding (1932) to effect that temperature between 34 and 41 F is not a prominent factor in determining incubation period but that higher temperatures decrease the period markedly, and that water temperature at hatching has an important effect. In one experiment, at 42 F, hatching occurred in 88 days but at 33 F in 191 days.

Battle (loc. cit.) noted two high mortality periods, the first during cleavage and to closure of the blastopore formation, the second during hatching. She found mortality rates of 2.6% per week for the first and 2.5% for the second. She quotes McGonigle as having found in Canadian hatcheries that with young parents the major loss is the early one, but with older parents the second. She also notes that Allen (1932) observed susceptibility of the eggs of Salmo salar to mechanical shock during organogenesis and at hatching.

3.213 Predators. We have heard that trout (Salvelinus fontinalis) eat salmon eggs during deposition but are not acquainted with attempts to confirm this. One of us (Elson) assisted H.C. White on studies of salmon egg survival in redds made by hand to closely resemble natural redds (White, 1942). In the spring small eels burrowed into the redds and had eggs and later newly-hatched fry in their stomachs. Elson (1942) reports insect nymphs, especially dragon-flies, taking very young fry in early summer. It seems likely such predators could also take eggs or newly-hatched alevins if the predators are active. In general, however, natural incubation in Canadian Atlantic salmon streams occurs during cold water conditions -- mostly near or below 1 C and above about 5-10 C only for a short period before hatching. Predation on eggs by cold-blooded animals would thus probably be at a minimum.

3.215 Mode of hatching. This is frequently observed in hatcheries. For a description, see Hayes (1942).

3.22 Larvae phase -- alevins.

3.221 General features of development. The term "alevin" is used to designate young salmon between hatching and absorption of the yolk-sac (Allan, 1965). Alevins are hatched with a yolk-sac which, at least in hatcheries, supplies their food for 29-65 days (Dymond, loc. cit.).

3.222 Rate of development, etc. Higher temperature shortens this period to 39-53 days (Dymond, loc. cit.). Alevins hatched under gravel are hardier than those reared in most hatcheries and about 15% heavier. As the yolk disappears, they start seeking their own food (Dymond quoting Belding (1932), Vibert (1954), and Jones (1959)).

3.223 Effect of environment on survival. Jones, quoting Stuart (1953) describes the behaviour of alevins of Salmo trutta which stay in the gravel for some time after hatching: this keeps them away from predacious, aquatic insects and other animals. Salmon alevins, at emergence from the gravel, were observed to be more gregarious than trout, however. We know of no detailed survival studies on salmon of this stage.

3.224 Time of first feeding. Alevins begin to feed as the yolk-sac disappears and they emerge from gravels. Under laboratory (= hatchery ?) conditions, alevins will begin feeding before complete yolk-sac absorption.

3.225 Type of feeding. In the Pollett River of southern New Brunswick, one of us (Elson) has observed newly-emerged alevins as early as mid May. At this time they were not seen to swim upward but appeared to feed on very small insects moving on the stones, and to live in the upper interstices of the substrate. Food (Jones reporting Stuart) will only be taken if it is moving.

3.23 Juvenile phase -- parr. Allan (1965) defines fry as the stage from yolk-sac absorption to June 30 in the year of hatching. Parr are defined as the stage from June 30 in year of hatching to seaward migration as smolts.

3.231 General features of development. About the end of the fry stage the fish develop characteristic cross bars.

Scale papillae and first scales develop when the fish are about 2½ cm long, on the posterior part along the lateral line. Scale formation proceeds in a pattern similarly to that for speckled trout (Elson, 1939) and is completed by the time the young fish are about 5 cm long (unpub. data).

Hoar (1939) reports that seasonal changes in thyroid activity are definite, there being an increase in spring and summer and a decrease in fall and winter. Saunders (1967) states that initial filling of the swimbladder of alevins, with gas, can be delayed by subjecting the fish to strong water currents. All parr he studied had negative buoyancy and those from rapidly flowing water were less buoyant than those from still water. In general, parr had less buoyancy than comparable sized speckled trout. Low buoyancy of salmon parr probably reflects (or results from) habitat preference. Most wild parr live on or near the substrate and in free-flowing current, but trout appear more often to live in intermediate water levels. Contrast in behaviour of wild versus hatchery-living underyearlings may also be associated with need for different habitats. Wild underyearlings, even more than older parr, live close to the bottom (Elson, 1942; 1967). In many hatcheries small fish are not offered conditions where they can rest on the bottom without conflict with their territorial proclivities.

Fatness, or condition factor ($\underline{k}$) of alevins is below 1 for the first 3 or 4 weeks after emergence, but then rises to and above 1 for the duration of most of the freshwater life. There is some waxing and waning of k in spring-summer compared to autumn-winter. Condition factor (k) of parr is similar to the k value for native adults (Hoar, 1939).

Growth rates vary between localities, even in one stream. Fast growth is usually associated with warmer waters. Availability of food may have some effect but systematic study of this factor has not been reported for wild fish.

Duration of freshwater life normally varies from 2 to 4 years but may extend to 7 or 8 years in northern rivers (Belding, 193 ; Power, 1958). A single year of freshwater life has occasionally been reported from Europe (Menzies, 1925), but such short freshwater life has not been soundly documented for Canadian salmon. Generally, parr which reach a total length of about 10 cm towards the end of a summer transform to the smolt stage the following spring (Elson, 1957). Depending on conditions then encountered, such as lakes or other barriers en route downstream, or excessively low stream flows, they may fail to complete seaward migration that year (Andrews, 1946, and unpub. data from the Pollett). When, at the normal period for seaward migration, young salmon obtain enough food to fatten rapidly, they may fail to complete metamorphosis and revert to the parr phase (Evropeitseva, 1958). Such fish would presumably be unusually large when they eventually migrated a year or more after first transformation (see also Section 3.51).

3.232 <u>Rates and periods of development and survival and factors affecting these</u>. As mentioned above, temperature of stream water, or at least something associated with it, affects rate of growth. With summer water temperatures commonly between 20-25 C, average lengths of July parr in the Pollett River in 1959 were for age 0+, 4.9 cm; for age 1+, 11.5 cm; for age 2+, 15.0 cm; among the older fish, 90% were age 1+, the 2+ year-class having mostly migrated that spring. One month later most of the underyearlings were 6-7 cm long. With summer water temperatures about 5 C lower, lengths of Northwest Miramichi parr in the same year but about 1 month later were for age 0+, 5.1 cm; for 1+, 8.1 cm; for 2+, 10.7 cm; and for 3+, 12.2 cm. Most Northwest Miramichi young salmon migrate as 3-year smolts (Allen, 1967; Forsythe, 1967). Growth rates are generally greatest in spring and early summer, often slow a little in mid summer, and may increase again in late summer and early autumn with seasonal food abundance. Slower growth continues late into fall, but probably ceases, or comes close to a standstill with water temperatures approaching 1 C or lower. In Maritime streams growth starts again as temperatures rise, usually in May, and has the characteristic fast growth pattern by early June (see also Section 3.43).

Average rates of survival observed in extensive Canadian studies of young salmon populations are summarized by Elson (1962). His figures apply to late-summer populations of young. Potential egg deposition to fall underyearlings, about 6%; underyearling to small parr (mostly 1+ years old), about 60%; small parr to large parr (mostly 2+ years old) about 40%; large parr to smolts, about 40%. Such values, however, may be modified by initial population densities (e.g. spawning) and by ability of the habitat to support certain numbers. For example, Elson (1962) found a limit of 5 or 6 smolts per 100 sq yd of stream as an upper limit for most of the streams he studied, but Saunders (1960) found up to 13 per 100 sq yd in a fertile Prince Edward Island brook. There may be similar limiting factors for younger stages. Numbers of wintering homes offering protection from anchor ice are suspected as limiting parr populations in some streams.

Predators on young salmon account for much mortality. White (1939) lists mergansers (*Mergus merganser* and *M. serrator*) and kingfishers (*Megaceryle alcyon*) as being especially active predators on parr. Sandpipers (*Actilis macularia*) eat some fry but have not been regarded as limiting factors. Eels take young salmon and can make serious inroads on newly liberated plantings of hatchery fry as well as on native stocks when eels are abundant (White, 1939; Elson, 1942, 1957; Godfrey, 195). Elson (1942) reports predation by invertebrates, especially leeches and dragon-fly larvae, under experimental conditions. Trout (White, *loc. cit.*) also eat young salmon. Mammalian predators appear not to be important as a rule (e.g. White, *loc. cit.*). The most serious losses to predators appear to be to mergansers (Elson, 1962) and control of these birds can result in about a five times increase in smolt output.

Competitors for space and food include speckled trout and eels (Elson, 1942). Other coexistent species, mostly cyprinids and catostomids in Canada, appear to be of minor importance for salmon production. We know of no reports on disease or parasites being limiting factors for wild young salmon. Pippy (1968) lists a number of parasites found in salmon smolts, both wild and hatchery-reared. These include the trematodes, *Crepidostomun farionis* and *Diplostomulum* sp. (the latter in the eyes); the acanthocephalans, *Echinorhynchus* sp., and the nematode, *Metabronema salvelini*, as the most prevalent parasites in Canadian smolts. In adult salmon the trematodes, *Derogenes varicus* and *Lecithaster gibbosus*, the cestode, *Eubothrium crassum*, and two species of the nematode *Anisakis* were most prevalent. A trematode, *Brachyphallus crenatus*, was quite common in 2-sea-year and older fish but was not found in grilse. Diseases, e.g. kidney disease, do occur in some Canadian hatcheries (Pippy, personal communication).

Pollution of freshwater habitat as by widespread use of pesticides, especially DDT (Elson and Kerswill, 1967) and mine effluents (Sprague, Elson and Saunders, 1967) can drastically reduce young salmon survival. Pollution by agricultural pesticides can also cause anomalous behaviour and mortality (Saunders, in preparation). With copper-zinc pollution reducing resistance of native fish, including suckers, to indigenous bacteria, the bacteria can reach epidemic proportions and kill salmon (Pippy, in preparation).

3.233 Effects of environment, subpopulations, density on rates of development and survival. Since about 1940 much FRB effort has been concentrated on studying production of young salmon in streams. Important techniques (Section 6.6) have included day- and night-time observation along streams (Elson, 1942); systematic seining, mostly with aid of d-c electric current (Smith and Elson, 1950; Elson, 1957, 1962, 1967; Godfrey, 1956; Murray, 1958) and examination of specimens. For some of the studies, populations were established by planting hatchery stocks in a stream (Pollett River) inaccessible to salmon because of barrier dams and falls but otherwise having characteristics of many recognized salmon streams. Where no references are given for statements below, information has been extracted from FRB Annual Reports of Stations, mostly St. Andrews.

With populations established by planting underyearling parr there was no difference in survival rate associated with wide dispersal versus no dispersal at liberation when fish were planted only in sufficient numbers to seed about 1 mile upstream and 1 mile downstream. Appropriate planting rates vary from about 15-55 late-summer underyearlings per 100 sq yd stream bottom, depending on fertility of the stream, suitability of habitat and absence of predators (Elson, 1957). But early mortalities can be expected to reduce numbers within a few weeks towards average values reported for established salmon streams under normal conditions. Approximate average values for late-summer populations are given by Elson (1967), per 100 sq yd, as 24 underyearlings, 20 small parr (10 cm and under and mostly yearlings) and 12 large parr (over 10 cm and mostly 2+ fish).

Because of homing (Saunders and Gee, 1964) and territory-holding proclivities of young salmon (Elson, 1942; Kalleberg, 1958; Keenleyside and Yamamoto, 1962), it seems likely that even under natural conditions of reproduction, wide dispersal of eggs, rather than concentration on a few limited spawning areas, would be necessary for full utilization of potential rearing habitats in a stream. According to Elson (1957), natural egg deposition at an overall rate of 200-300 per 100 sq yd should maintain production at as high levels as most streams can support. Similar rates of deposition still occur in such streams as the Miramichi.

Whether populations of other fish species much affect production of salmon on rearing grounds has received little study. Elson (1962) reports that salmon benefitted from merganser control, on the Pollett, more than other fish, with the possible exception of eels.

Comparative values of different types of habitat for young salmon are shown diagrammatically by Elson (1967). Generally speaking, fine to coarse gravel bottom and swift riffles are favoured. In a 12-mile section of the Pollett, with rather uniform gradient of about 35 ft/mile and with much gravel and cobble bottom, production rates from potential egg deposition to underyearlings and from either native or planted underyearlings to smolts were about twice as high as on a lower section of the same stream where gradient was 16 ft/mile and the bottom had more bedrock and compacted sand or gravel than the upriver section (SA 64/18).

3.234 Differences from adults in diet, feeding habits, etc. Since young salmon live in streams and maturing fish in the sea, there are conspicuous differences. Young salmon feed almost altogether on insects, mostly in aquatic phases. Occasionally they take aerial and terrestrial insects just above or on the surface. We have also observed parr picking up insects as they crawled over stones of the substrate, as well as "grazing" on anchored simulid larvae. Fish has rarely been recorded as a food item and then usually as of only casual occurrence. Adult salmon at sea take small fish (herring, capelin, launce) and pelagic invertebrates, but do not feed when they return to fresh water other than occasionally picking up insects or other aquatic organisms. For further information on food and references, see Section 3.4.

3.24 Adolescent phase -- smolts. Smolts are defined as fully silvered parr migrating to sea (Allen, 1965). This stage is preceded by large parr, in their final spring, putting on a coating of guanine (silver parr of Allan, 1965). Physiology of quanine deposition on young salmon is currently being studied at the University of New Brunswick. In nature, transition through silver parr to smolt is a gradual process, probably depending much on water temperatures. Seaward migration may begin when fish are in partially silvered condition or not until after silvering is long completed. Hence, any brief definition of smolt is necessarily arbitrary and the term is subject to elasticity in ordinary usage.

Hoar (1939) noted that migrating, well-silvered smolts have a condition factor (k) under 1.0 and that only at the alevin and kelt stages are similarly low k values experienced. According to Allen's (1941) studies, active smoltification is not likely to be conspicuous until spring water temperatures rise to about 7 C, when fast growth commences in river-dwelling salmon. In the Pollett studies, no silvery smolts were seen in early May, by mid May well-silvered smolts were evident, and by the end of May, most migration was completed. Transformation from late parr to smolt stages appears therefore to require only a few weeks. In most Canadian streams this transformation occurs in May and June.

Large parr may, however, commence to show some guanine deposition even in late autumn. Some parr even move downstream in late October and November. Little is known about the extent of such migrations, or whether the individuals involved go all the way to sea and contribute proportionally to marine populations. Pre-smolt parr overwintered in experimental tanks and in hatchery ponds may become smolts several weeks earlier than wild fish wintering in nearby streams (personal communications from R.L. Saunders and Alfred Meister). Whether this is associated with higher temperature or the physical nature of their environment is not known. But even large, hatchery-reared, well-transformed smolts liberated a month or two in advance of normal smolt runs have given below average returns (unpublished data from St. Andrews and Maine). Scales on smolts are fastened much more loosely in the skin than on parr. They slip off very easily with any abrasion of the skin surface such as the handling incidental to marking and tagging.

Tagged smolts, at least, are subject to predation by large fish-eating birds, including mergansers on rivers and cormorants (unpublished Maine data) in near-shore tidal waters. Tags have also been reported from cod (Murray, 1967) and pollock stomachs (St. Andrews data). On some streams trout anglers may take substantial numbers of smolts, failing to distinguish them from small trout. Smolts, after feeding ravenously during migration, take angler offerings readily.

Commercial fishing gear for small fish may take hundreds of smolts on occasion (Comeau, 1909, and personal communication from various individuals). Late-summer post-smolts (defined by Allen, 1965, as the stage during the first year of life in the sea) may be taken in the sea by gear set for other small fish, several hundred sometimes being taken in August in some Bay of Fundy herring weirs (St. Andrews data).

Food of smolts in rivers consists mainly of aquatic insects, etc. We know of no studies of food while smolts are passing through estuaries. August post-smolts in the Bay of Fundy had eaten various small marine fish, including herring and pollock about 3 inches long.

For migrations of smolts see Section 3.51.

3.3 Adult phase

"Salmon" is the term used by Allen (1965) for fish which have accomplished their first year at sea. The term has subdivisions relating to number of winters spent at sea before first maturity. A grilse is a salmon which matures after 1 winter at sea. Most salmon spawn but once, then disappear. A few may spawn several times (Dymond, 1964), up to five or six (Medcof and White, unpub.) (see also Section 3.152).

3.31 Longevity.

3.311 Average life expectancy for Canadian salmon is 1+ sea years for grilse, 2+ sea years for most, perhaps two thirds, of larger salmon, and 3+ for the rest. Total life expectancy includes the pre-smolt river years, most commonly 2 or 3 years but occasionally up to 8. About 5 years is thus probably a reasonable average value for overall life expectancy for Canadian Atlantic salmon.

3.312 Maximum life expectancy. For fish from far northern rivers with high smolt age, this might be up to 10 years to first spawning. Fish which spawned four times and were 13 and 14 years old are reported by Dymond (loc. cit.).

3.313 Variations in longevity. The percentage of females that survive spawning is higher than of males. Since on the whole more males than females seem to mature as grilse, life expectancy for males is the shorter (Dymond, loc. cit.). Shorter life is therefore to be expected in streams with predominantly grilse runs. These are often warm streams with a high proportion of 2-year-old smolts. Longest life is for salmon from cold streams favouring high smolt age and where populations have long sea life to first maturity.

The percentage of fish which live to spawn two or more times is reflected in the percentage of such fish in adult catches. Dymond (loc. cit.) reports 3-34% for various Canadian rivers, with particular ranges being more or less characteristic of certain streams. Respawners appear to be relatively more abundant in Canada than in Europe. In Canada many spawners over-winter in ice-bound rivers and provide early spring angling (Kerswill, 1955). In Europe many rivers do not become ice-bound so that rates of metabolism for salmon and organisms which attack them remain high, which may contribute added mortality. An interesting value given by Dymond is 14% respawners in Greenland reported in 1953. Comparison with present proportions in Greenland might throw some light on possible recent changes in exploitation rates. Around 5-10% respawners appears to be an average for Canadian populations.

Kelts (spawned salmon not yet recovered (Allen, 1965)) have been reconditioned by feeding them in fresh water (Huntsman, 195 ; AST, 1946) and by experimental manipulation of their biochemistry (FRB Halifax Sta., 196).

3.32 Hardiness.

3.321 Limits of tolerance to changes in environment. Principal limitation for adult salmon would appear to be temperature. Death in rivers from heat stroke with high water temperatures occurred at about 29-30 C (Huntsman, 1942). Salmon in the sea have been taken in surface nets, both at Greenland and in the Bay of Fundy at slightly under 2 C. They feed vigorously in the sea at temperatures between about 5-15 C (unpub. data). They can be reared in fresh water throughout life, both in hatcheries and when planted in lakes with no suitable outlet, as well as occurring in "landlocked" form in some waters where they could get to sea.

3.322 Limits of tolerance to handling and life in aquaria (see also 3.312). At. St. Andrews, salmon have been grown from smolt stage to maturity in 6-ft diameter circular tanks in both fresh and sea water. These fish have been removed from the water monthly for extracting growth, etc., data. Smaller fish are equally tolerant. Large fish especially are easily excited by unaccustomed movement about or impact on the tanks (E. Henderson, personal communication).

3.324 Variations in hardiness with age, etc. In respect to temperature, small parr were found to die at 33.8 C, whereas larger parr died at 32.9, acclimated grilse at 30.5, and fresh-run grilse at 29.5 C in the Moser River. In one series of observations with rising afternoon water temperatures, the only large salmon present died before any of the 4 grilse died from a school of 12 grilse. In similar heat-associated death elsewhere, with slightly less extreme conditions, most of the salmon that died were large, a few were medium, but none of the many grilse died (Huntsman, 1942).

During the marine phase scales, like those of smolts, are comparatively loosely attached. As the fish become river mature, the skin thickens and the scales become firmly embedded.

Even in the marine phase, salmon can sustain severe physical damage, as from wounds caused by predators, and survive, as shown by scars. One of us once tagged an 18-lb salmon from a weir in Saint John Harbour which had a flap of skin and flesh about 3 inches by 4 inches peeled back along from the gill slits, believed to be seal damage. The fish was recaptured about 3 months later with the wound healed. In fresh water, however, wounds and skin abrasions, as from sea lice (*Lepeophtheirus* sp.) are subject to attack by fungus (*Saprolegnia* sp.) and perhaps other pathogens. These severe secondary infections may cause mortality. External damage of the skin surface may also lead to difficulties in maintaining osmotic balance, but the extent of damage which becomes critical is not known.

3.33 Competitors

Almost nothing is known about competition between salmon in the marine phase and other species for food. Competition with other species for spawning areas has not been recognized. Speckled trout tend to use somewhat different types of ground and the spawning season is earlier; the same applies for rainbow trout as far as limited observations (J. Catt, personal communication) have shown. Possibly brown trout and salmon may compete but *S. trutta* occurs in few

Canadian salmon streams. In experimental attempts to introduce pink salmon, Oncorhynchus, to a Newfoundland stream, the returning pinks completed spawning before the end of September, but Atlantic salmon did not spawn until some weeks later (A.A. Blair, personal communication).

3.34 Predators

Survival rates from seaward migrating wild smolts to returning adults have been reported as from under 1% to at least 10% (Dymond, loc. cit.). Elson (1957) gives a mean, with standard error, survival rate for experiments from 1938 to 1953 of 8 ± 1.5%. Little is known about the life of salmon at sea, but the low survival seemed to Dymond to indicate severe predation throughout life. Seals, both harbour and grey, are reported as frequently taking salmon gathered near river mouths. They have been observed taking salmon from nets. Salmon are also taken by sharks at sea (Dymond, loc.cit.). Porpoise (Phocaena phocaena), in the opinion of Saint John drift-net fishermen, take salmon at sea (Hoar, 1938). The importance of such predation needs study.

In rivers, seals sometimes follow salmon runs into the lower freshwater reaches. Otters may take a few salmon. We have observed bald eagles eating kelts in the spring. But, in general, predators on adult salmon in fresh water, other than man, have not been reported as serious in Canada.

3.35 Parasites, diseases, abnormalities

3.351 Parasites and disease. In common with other aspects of marine life, there is still scant information in these areas. However, within the last two years studies of parasites have been given impetus by the need to distinguish various stocks of salmon contributing to the new Greenland fishery. Parasites may serve as biological tags.

The lamprey, Petromyzon marinus, spawns in the Miramichi, Saint John, and other Maritime salmon rivers. That it attacks salmon was found by Keenleyside (SA 57/136) for the Miramichi. About 1% of salmon caught in the estuary had either young lampreys attached or bore lamprey scars. For adults examined after they entered fresh water, incidence of attached lampreys and scars was less than half the estuarial incidence. Lampreys do not appear,on these data, to be a serious menace to salmon.

The salmon sea louse, Lepeophtheirus salmonis, is commonly found on salmon taken in estuaries and marine waters, whether the fish are entering their natal river or as far distant as the shores of Greenland. White (1940, 1942) studied life history of this parasite and some of its effects on salmon entering a Nova Scotia river.

A tapeworm, Eubothrium sp., is found in the gut of practically all salmon taken at sea. Other parasites commonly found in Canadian salmon include Salmincola gordoni found on Newfoundland and Labrador but not on mainland smolts; a larval round worm, Anisakis, is probably picked up in salt water; Diplostomulum sp. occurs in the eyes of some Canadian smolts and adults and is particularly abundant in the Margaree, Cape Breton, hatchery.

Occasionally salmon in fresh water are reported as moribund or dead. Cases involving damage from sea lice (White, 1940) and high temperature (Huntsman, 1942) have already been referred to, as has also a condition where copper-zinc pollution gave rise to an epidemic infestation of salmon and other fish by Aeromonas liquifaciens in the Northwest Miramichi River in 1967 (Pippy, in preparation). Extensive epidemics of such diseases as furunculosis and ulcerative dermal necrosis in European salmon or columnaris disease of west coast salmon have not as yet been reported from Canadian Atlantic salmon waters.

3.352 Injuries and abnormalities. Injuries from predators have been mentioned in Section 3.351. Frequently salmon which have recovered from such injuries are acceptable on the market. In 1967 there were increasing reports of salmon with rubber rings firmly fixed around their bodies, frequently just anterior of the dorsal fin. Sometimes these are embedded in the flesh, leaving open, necrotic wounds. The bands appear to be cuffs of rubber gloves, such as used in fish plants and on fishing industry factory ships. Another type of injury drawn to attention in 1967 involves extensive bruising and blood seepage into muscle areas. The cause of this infartion and its incidence are under investigation in 1968.

Ability to recover from mechanical damage is mentioned above. Even with some of the salmon showing extensive infartion in the flesh, superficial recovery has been observed to include regeneration of scales, with up to 2 or 3 circulae, on the damaged area.

Effects of such damage on the ability of the individual to survive are, like most other aspects of marine life, unknown.

3.4 Nutrition and growth.

This section will be confined mostly to information about salmon under natural conditions and to results of laboratory or field experiments. Only a little attention is given to a considerable body of knowledge, including Russian, on feeding and growth under hatchery conditions.

3.41 Feeding.

3.411 Time of day. Hoar (1942) studied diurnal variations in feeding activity of young salmon. He found there was much less active feeding between 1-2 hours after sunset and 2-3 hours after sunrise than during the rest of the daylight hours. The nightly depression was attributed to sleep, not just reactions to temperature and light. A mid-day slackening, but not cessation, was attributed to both rising temperature and strong light. Hoar's observations were made in warm summer weather.

In the marine phase, as judged by success in open-ocean fishing, salmon come near the surface and are actively feeding, primarily during dusk to dawn hours. Whether they also feed at greater depths in daytime is not known. Experimental ocean longlining for Pacific salmon indicates most active feeding of *Oncorhynchus* sp. around dusk and dawn (personal communication from Nanaimo staff).

While mature salmon back in rivers do not feed in the sense that young salmon or those in the marine phase do, they do sometimes respond to moving objects which may be ingested. According to Knobs (1964) such activity tends to be a maximum in mid-forenoon and mid- to late afternoon. But many other factors such as weather conditions and migratory behaviour of the fish may alter this pattern.

3.412 Place of feeding - general. Young salmon find their food usually within their own home territories compassing perhaps only a few square yards. These are frequently in rapid, or riffle areas where the aquatic insects on which they feed grow most abundantly.

Feeding areas for salmon in the marine phase are less well known. Post-smolts with food in their stomachs are sometimes taken in shore-based weirs and traps for other small fish. Larger fish have been recorded as taken on hook and line during offshore fishing operations, including on Georges Banks and the Grand Banks. Many salmon find their way to the West Greenland area where they feed in the open ocean, along shore and well into the extensive fjords. Fishing operations tend to indicate that feeding is at the surface and occurs largely at night. Salmon with food in their stomachs are also taken, before about mid-July, in the shore nets of northern Cape Breton Island and in the drift-net fisheries of the Bay of Fundy and Miramichi areas. Foods reported for salmon taken in salt water include small pelagic forms such as young gadoids, lance, capelin, smolts, cephalopods, amphipods (Day, 1940; Hoar, 1935, 1936; Jensen, 1967; Templeman, 1966).

3.413 Manner of feeding. Young salmon pick up much food while it is drifting down past them in the stream water. They also rise to the surface for floating insects and we have observed them picking up aquatic nymphs moving over the stones of the bottom. Usually they take moving organisms but one of us (P.F.E.) has observed individual parr which appeared to be "grazing" on colonies of blackfly larvae (Simulidae) attached to stones in a riffle. Parr frequently leap clear of the water to catch low flying terrestrial insects.

The food organisms found in marine salmon suggest they, too, feed on small animals moving in the water, especially close-schooling forms.

3.414 Frequency. Parr (Hoar, 1942) have two daytime periods of intensive feeding, but may take food at any time. Marine salmon appear to feed at the surface between dusk and dawn, but whether they also feed at other times and depths is not known.

3.415 Variations in feeding with season, size, maturity, etc. Parr feed from spring through fall. Judging by patterns of growth on scales, there is sometimes a period of less intensive feeding in mid-summer. Whether this results from food scarcity, high temperature affecting activity or metabolic balances between anabolism and catabolism is not known. According to Allen (1941), in the spring intensive feeding and growth commence as water temperatures rise to and above about 7°C, though some feeding occurs below this. Examination of Pollett River parr scales indicates that growth, though slow, continues into October and November when water temperatures drop well below 5°C, but no indications of recent growth were seen on the scales of winter-caught parr, when water temperatures were under 1.5 or 1°C (unpub. data). Elson (1940) says that terrestrial forms were used more in the late summer and fall than earlier in the year. Keenleyside (1967) found that with scarcity of their usual foods, resulting in this instance from DDT pollution of a stream, parr would turn to other available forms including miscellaneous Diptera larvae, snails and earthworms.

We know of no published reports of seasonal feeding habits for the marine phase. Other salmon which approach shore in eastern Newfoundland in November and later winter are, though large, not sexually mature, and these have food in their stomachs (A.A. Blair, personal communication). By inference from scale patterns it seems likely that in the coldest months feeding may decline. Salmon caught in Greenland at 2-4°C had food in their stomachs, though scales showed commencement of winter-ring formation indicating slowed growth. Sea-winter rings on some marine salmon are much more pronounced than on others, perhaps indicating different feeding habits, or temperature associations, or both. Detailed examination of scale patterns of salmon caught at sea in various seasons is required for knowledge on marine life.

Kelts descending the Pollett River in spring have been observed to have a few aquatic insects in their stomachs, but it is not believed that an important amount of food is ingested until they reach estuarial or salt waters.

3.416 Abstention from feeding. Mature salmon approaching rivers cease feeding some time before entry. Hoar (1935, 1936) and Day (1940) report most stomachs examined at Margaree after mid-July were empty. Whether late-run fish entering rivers in October cease feeding in mid-summer is not known.

3.42 Food.

3.421 Types eaten. River-dwelling parr eat primarily aquatic stages of Chironomidae, Ephemeridae, Plecoptera and Trichoptera. The very small underyearlings use primarily small chironomids. Large parr use the larger forms (Elson, 1940; Keenleyside, 1967; White, 1936). Importance of various kinds devoured appear to depend to a large extent on their availability (Keenleyside, loc. cit.). Terrestrial insects and other miscellaneous forms, including younger salmonids, play a relatively more important role in late summer and fall (Elson, 1940).

3.422 Volume of food eaten. Very little information on volume eaten under natural conditions is available. Keenleyside (1967) reports the mean volume of stomach contents for 157 fry as about 0.02 ml and for 247 parr as about 0.13 ml. White (1936) reports an average of 83 organisms, mostly chironomid larvae, in stomachs of fry about 0.29 cm long.

In laboratory experiments where fish were given all they could eat with little wastage, 10 g (about 10 cm) parr ate 0.7 g (about 0.6 ml) of food per 24-hr period; 300 g (about 30 cm) post-smolts ate 12 g; and 1.7 kg (about 50 cm) grilse ate 34 g. Temperature affected food consumption. In the range 10-16°C, food consumption for all sizes was noticeably higher than below 10°. With falling temperature, food ingestion decreased more rapidly in the lower than in the upper range (E. Henderson, personal communication).

We have no records of volume of food eaten by larger salmon but have seen as many as half a dozen 6-inch capelin in stomachs of salmon landed in the Miramichi drift-net fishery in mid-July. European workers in Greenland have unpublished data on amount of food found in salmon stomachs there.

3.43 Growth rate.

3.431 Scale readings for determination of age in relation to size have been done on many thousands of Canadian salmon of all ages. Earlier work includes fish from Miramichi, Margaree, Moser, Saint John and other fisheries. Since 1950 most work of this kind has involved adults from Miramichi fisheries and young fish from streams affected by forest spraying with DDT. Results give useful background information on life histories, mainly supporting previously published work. There is need for development of scale-interpreting techniques which will yield more detailed information about growth characteristics of the stocks used in various fisheries and characteristic of particular rivers.

Further comments on growth rates, relations to temperature, food, etc., appear in earlier sections of this review (3.23, 3.24 and 3.33).

3.432 Condition factor. Hoar (1939) studied weight-length relationships of Margaree and of Saint John salmon at various stages of their life history. Using length^3 relationship he found the coefficient of condition, "k" to be close to 1.0 (cgs system) at most stages, but newly emerged alevins, smolts and kelts tended to be comparatively thin ($k < 1.0$). As pointed out by Hile (1936) the validity of comparing fish of quite different lengths on the basis of "k" is questionable. But Hoar's values none the less provide a standard against which fish of similar lengths may be compared. No reason is seen to question the validity of Hoar's comparisons between male (stouter) and female (more slender) parr of comparable ages. It is certainly our experience that smolts are usually thinner than untransformed parr of similar length, Hoar's data indicating fish taken farther from the Saint John River are fatter than those taken nearer to or in the river are in accord with data gathered in the Miramichi area in 1967 for fish taken in commercial fisheries (9-11½ lb at 75-80 cm) compared to those taken in fresh water (8-9¾ lb for the same range of lengths).

Additional studies of weight-length relationships as well as age and growth patterns for salmon associated with particular areas should contribute to imaginative selective breeding studies.

3.433 Relation of growth to feeding, spawning, etc., activities and to environmental factors. Growth rate is closely related to amount of food ingested (E.B. Henderson, personal communication).

With the onset of sexual maturity and cessation of feeding, growth essentially stops. Fish lose weight to the extent of about 20 to 50% of the weight at which they entered the river. In the Miramichi (Kerswill, 1955) kelts from fall-run fish contribute more than those from early-run to spring angling for "black salmon" most of which are in fact about as silvery as smolts. The late-run fish probably do not lose as much weight as the early-run fish. If kelts survive they grow at as good a rate as virgin fish (Allen, Saunders and Elson, in preparation). Jones (1959) reports an 8-lb kelt returning in 18 months and weighing 28 lb, and out of a large number weighing 5.4 lb as kelts, average weight at later recapture was 11 lb.

Aside from spawning the principal factors affecting feeding are, as far as known, temperature, discussed earlier, and, presumably, availability of food. Pollution as by DDT (Elson, 1967; Keenleyside, 1967) or copper-zinc effluent from mines (Sprague et al., 1965) sometimes greatly reduces production of salmon food. Such conditions can result in thin parr though the data available (unpublished) do not necessarily indicate much reduction in growth in length. Such conditions when observed in nature have also been accompanied by heavy mortality of young salmon from poisoning, so that direct effects of food scarcity may not have emerged clearly.

Food conversion factors for laboratory post-smolts fed on a mixture of liver, herring and commercial trout meal were relatively constant (0.28 to 0.36) whether the fish were held in fresh, brackish, or full salt water (SA '64/pp 23-41).

At St. Andrews studies have been made of growth and maturation in respect to salinity under laboratory conditions, during 19 post-smolt months. Growth rate trends were relatively constant over the period. Most growth occurred in fresh water, average length of the grilse being 53.7 cm in fresh water, 50.0 cm in 15‰, and 46.7 in 30‰. More of the fish in fresh water matured as grilse, too (80% as against 73% in 15‰ and 40% in 30‰. (SA '67/12)

In laboratory studies a diet containing a high proportion of herring (approx. 40%) resulted in morbidity and death if fed for more than 4 months. Despite this the fish made good growth until the onset of morbidity. Adverse effect was believed due to an excess of thiaminase inducing avitaminosis (B_1). (SA '65/p E-16)

Exposure of post-smolts to regularly increasing photo-periods resulted in more growth than exposure to moderately long or decreasing photo-periods (SA '67/12). Young salmon reared from the yolk sac absorption stage in brackish water (salinity 2-12‰) grew faster (up to 15%) and had a much better survival rate (75% as compared to 40%) than those reared in fresh water. (SA '65/E-20)

3.434 Growth and population density. We know of little useful information on this. Elson (1967) reports that in 1955 hatching of salmon in the Miramichi and other Maritime streams resulted in densities of underyearling parr populations about twice the commonly observed value. Despite this, these under-yearling parr also grew faster than in most years.

In preliminary laboratory experiments with controlled food supply, more fish occupied an experimental stream-type habitat, establishing homes, when food was more abundant (P.E.K. Symons, personal communication).

3.435 Food-growth relations. Instantaneous growth rates for Atlantic salmon have been measured in the St. Andrews laboratory. They decrease with increasing size, being approximately inversely proportional to the size of the fish. Measured in the temperature range of 12-16°C, instantaneous growth rates in length per day for fish of various sizes were:

Length of fish:	3-6 cm	6-15 cm	15-25 cm	25-30 cm	40-50 cm
Growth/24 hr	0.100	0.0065	0.0060	0.0040	0.0015

(R.L. Saunders and E.B. Henderson, personal communication). Power and Shooner (1966) report better growth for young salmon in an estuary, at 0.8 mm per day, than for fish of similar age in adject freshwater reaches of the Nabisipi River. Differences in food were offered as part of the explanation. Capelin eggs and amphipods in the estuary and Corixidae in the river were important food constituents.

3.44 Metabolism.

3.441-3.443 Metabolic rates, standard and active - no information.

3.444 Endocrine systems. Hoar (1939) described functioning as well as development of the thyroid gland in salmon. In addition to being more active in summer than in winter, this gland shows pronounced hyperplasia at smolt transformation. Unpublished histological studies on hyperplasia of the pituitary during sexual maturation of adults, by Dr. Henry Heyl, have already been referred to. Pituitary extract has been used to induce artificial spawning in other species of fish (Pickford, 1953).

3.445 Osmotic relations. A number of workers have studied freezing point depression of Atlantic salmon blood. Perry (1961) gives values of -0.59°C for alevins, -0.61°C for parr, -0.58 to -0.65 for smolts, -0.77 for adults in 15‰ sea water, and -0.65°C for adults in fresh water.

The mechanisms of osmoregulation are by no means fully understood. Data on osmoregulation in respect to various conditions of salinity, temperature and photo-period are being accumulated at St. Andrews and at the University of Guelph (SA '65/ p E-20). Further studies are important to better understanding of salmon growth.

3.5 Behaviour.

3.51 Migrations and local movements. The migratory behaviour of Atlantic salmon has been the subject of much writing; some is based on factual knowledge but much has been speculative. Young, river-dwelling salmon are essentially home-loving fish but those in the marine phase are generally believed to migrate to distant sea feeding grounds, returning to natal rivers as they mature sexually.

Territoriality in young salmon, described most recently by Keenleyside and Yamamoto (1962) and a tendency for parr displaced artificially as much as 700 ft to return to their own homes (Saunders and Gee, 1962) does not altogether prevent the fish from wandering at certain times. Where counting fences that will intercept small fish have been operated through long seasons on salmon streams, it is not uncommon to observe numbers of parr moving up- or downstream during periods of high water in autumn, during adult spawning season, and occasionally in spring, during smolt migration (Huntsman, 1945; unpublished data at St. Andrews). The extent of such migration has not been well studied but Elson (1957, 1962) reports that scattered plantings of hatchery parr do not result in effectively populating a stream if liberations are more than 2 or 3 miles apart.

Ocean migrations, however, take salmon far distant from their home streams (Saunders et al., 1965). Huntsman has frequently (e.g. 1948) advanced the hypothesis that many of the fish travelling to distant places are merely wandering and may become permanently lost to the natal river. He concludes that most salmon from large rivers which return there have spent their marine life within the seaward sphere of influence of the river; but that salmon from small streams may well lose contact and their return to the natal stream is somewhat fortuitous (views summarized in Dymond). Results from many experiments involving tagging of adult salmon at sea (Canadian studies to 1953 summarized in Elson, 1957; others by Blair, 1956, 1957a, b) show that many salmon travel long distances in the sea before entering rivers. There is one authenticated instance of a salmon being caught far away, then returning to its natal stream (Huntsman, 1942). Of about 951 salmon tagged in Greenland in 1965 and 1966, only 5 have subsequently been recovered in European (3 in Scotland) or North American (2 in Canada) waters. Many of the tagged fish had suffered some net damage when tagged (W. Munro and A. Swain, personal communication). Information on origin of stocks in fisheries, even distant, is rapidly accumulating, but if even home fisheries are to be maintained there is urgent need for additional information on return to home areas from distant places, including survival rates.

3.512 Function of migrations. The movements of parr, especially during spring and autumn periods of high river flow would perhaps better be described as fortuitous wandering, rather than purposeful migration. It would seem that they should contribute to some extent to wider dispersal of the young. In some streams lacking good wintering quarters in summer rearing grounds and with severe winter conditions, including much frazil ice formation, such movements may contribute to increased over-winter survival if the parr reach more suitable habitats.

The principal function of salmon migrations to the ocean is to permit the river-reared young to forage on the much greater food resources of the sea and to bring sexually mature adults back to the reproductive areas of the species in suitable freshwater streams. Streams by themselves cannot supply the food resources necessary to support large populations of Atlantic salmon throughout their life cycle.

3.513 Direction of movements. When parr move from one place to another, seasonally or with high water at any time, the movement is perhaps well described as "wandering". It may initially be downstream, especially with a spate, even into estuaries, and subsequently upstream, perhaps into other streams entering an estuary into which they got (Huntsman, 1945). They have also been observed to move upstream with small increases in current flow in a brook (Elson, 1942, MS 329, XXVII).

Smolts move, either actively or passively, downstream. The precise mechanism of this downstream passage has not been fully analysed. Sometimes the fish can be observed swimming in a downstream direction; at others, they swim against the flow in such leisurely fashion that they pass downstream. Huntsman (personal communication) contends that the smolt seaward movement is not an active migration but merely a failure to maintain location in the river by thin, tender-skinned fish. Smolts in hatcheries have been observed to reverse their usual direction of swimming against the water current in circular or square ponds and swim in the direction of water flow. We have watched such a sudden mass reversal of direction occur with the onset of dusk early in the normal smolt season; with increasing light after sunrise there was a mass reversal from downstream to upstream swimming; around the peak of natural smolt season downstream swimming was maintained day and night for a couple of weeks or so. Kalleberg (195) was the first to make such observations, in Sweden. Canadian hatcheries have reared increasing numbers of salmon to the smolt stages in the last 10 years and similar observations on behaviour have been reported from at least two hatcheries for fish held in circular or square ponds.

Elson (1962) and White (1940) have examined some of the environmental factors associated with the seaward migrations of salmon smolts. Temperature was seen as a most important factor, runs usually getting into full swing only after water temperatures reached and exceeded about 10°C. Increase of stream discharge (freshets) brings increased daily runs, as also may decreased light intensity. On the Pollett River when upstream bulldozing of stream gravels gave muddy daytime water without rise in discharge, more smolts descended in daytime than with clear water. Usually most smolts appear at counting fences during the hours from late afternoon to early morning, with peak movement appearing at dusk and dawn (Hayes, 1953).

Without freshets, hence usually continually dropping stream water levels and rising temperatures throughout the season of smolt run, some smolts may fail to complete seaward migration. On the Pollett in 1964 it was estimated, from trapping smolts in a downriver weir and electroseining in upper waters in July after completion of the smolt run, that about one-third the upriver smolts failed to descend that year (SA '64/18).

Two Russian workers (Evropeitseva, 1959, 1963; Malikova, 1959) have examined the behavioural, physiological, and biochemical characteristics of parr as they develop into smolts. Analyses for fat content showed less fat in smolts than parr. Changes in metabolism with smoltification included avitaminosis and decreased resistance. Temperature required for smoltification varied from 6-7 to 11-12°C. A sudden increase in temperature, though, accompanied by a surfeit of food, could delay the process of smoltification because the fish accumulated too much fat and reverted, before complete transformation, to a silvery parr stage. This may be the type of history recorded on some scales from wild smolts delayed in large lakes with, at least temporarily, a good food supply and from smolts of northern rivers where early summer conditions come late but fast (G. Power, personal communication). Note that Huntsman's contention that smolts are thin, weak fish does have a certain common basis with the Russian findings.

Additional research, including both biochemical and behavioural studies in the laboratory as well as perceptive field observations, are necessary for a better understanding of the seaward movement of young salmon for which, without imputing any purposive behaviour patterns, we find objective use of the term "migration" acceptable.

[Authors' note: In examining the above section on "Direction of movements" for smolts, it is clear that the latter part of the statement on physiology, etc., should be listed under another subheading. It also seems best to divide the section on Migration into two main parts -- "Feeding (= seaward and marine) migration" and "Spawning migration", but drastic reorganization cannot be undertaken at this time.

Because of the requirement for a total statement within another day or so, it is equally clear that the remaining matter cannot possibly be given treatment comparable to that so far presented. The present text from here on covers mostly work reported through the St. Andrews Station in Annual Reports and is based on an assembly of material prepared by both authors jointly in February 1968. (P.F.E.)]

Marine phase. Beginning in 1950 extensive new smolt marking studies were initiated on the Miramichi River. Some were already going on from the Pollett River (New Brunswick, head of Bay of Fundy). Post-smolts from this and other Bay of Fundy-Gulf of Maine rivers are taken in herring weirs at the head of the bay on the Nova Scotia shore each year in July and August (SA '63/E-20). In proportion to numbers liberated, more fish from Gulf of Maine rivers were frequently taken than from New Brunswick rivers. The general pattern of catches indicates that water circulation contributes substantially to movements and availability of fish. In 1953 fin-clipping studies were extended to the Port Daniel River (south Gaspé shore) and in 1954 to the Little Codroy (southwest corner of Newfoundland). The studies have yielded much information about the contributions of various river stocks to commercial and sport fisheries. Early experiments involved identification of smolt origin by fin-clipping. Beginning in the early sixties there has been increasing use of plastic tags, commonly serially numbered and affixed to smolts with stainless steel wire (Swedish, or Carlin pattern) or polyethylene filament. It seems likely that the tags are more readily recognized than fin-clips, by fishermen. Moreover, since these programs began there has been steady and annual indoctrination of Fisheries Officers and fishermen in respect to reporting returns. Results of Port Daniel fin-clipping studies are reported by Bergeron (1959); early results of Miramichi and Pollett fin-clipping studies were summarized by Kerswill (1955); while all Miramichi results to early 1960's are in final stages of preparation for publication by C.J. Kerswill; Little Codroy results, by A.R. Murray, are also in final pre-publication stages.

These studies have shown:

(1) Quite a large proportion of salmon taken in marine fisheries far removed from rivers of origin, especially fish which mature when older than grilse. An even larger proportion are taken near the home river. Distant recaptures include the coasts of Labrador (especially in July) and eastern Newfoundland as well as, since 1961 (Saunders et al., 1965) Greenland, the latter in autumn months.

(2) Almost no (under 1%) recaptures of mature native adults in fresh water other than their natal streams under ordinary conditions. A higher, but still a very small percentage of hatchery-reared smolts have been taken in freshwater streams other than those in which they were liberated, but many more have been recaptured in the stream of liberation, as well as in near and distant commercial fisheries. An exception to the above statement about high degree of return to natal stream or stream of hatchery-smolt liberation is provided by Northwest Miramichi records since 1960. Since copper-zinc pollution of this stream became a not uncommon component of its environmental features, upward-moving salmon have shown tendency to avoid this stream during times of high pollution (Saunders and Sprague, 1967). Within this period a substantially increased proportion of salmon tagged as smolts descending the Northwest Miramichi has been taken in other branches of the Miramichi system.

The overall picture of marine recaptures is such that, if one considers the spotty locations and limited seasons of salmon fishing, much of the explanation for the distribution pattern correlates with surface movements of sea water having temperatures within the ranges known to be acceptable to salmon. In those fishery areas where the matter has been examined, early catches (to about mid July) have food in their stomachs and it seems logical to assume that availability of food must have bearing on where salmon are found. While some salmon come to Canadian (and European) shores from places as distant as Greenland, there are not yet facts to indicate that a high proportion of distant salmon return to natal rivers. Huntsman (1952, 1954, and in preparation) sees salmon movements in the sea as, at best, wandering, biased by environmental, largely physical, factors. He does not consider "migration" a suitable term for such movement. From tagging in Canadian coastal and open-sea fisheries it is clear, however, that many salmon eventually enter rivers hundreds of miles from where they were a few weeks or months previously (see Dymond for pertinent references). Lacking is confirmation that such fish are indeed returning to natal rivers. That occasional fish, both native and especially those of hatchery-reared smolt origin, enter rivers other than the natal stream or stream of smolt liberation, is shown by records at St. Andrews and in Maine. Smolts liberated in the Miramichi have been angled in fresh water as far away as the Jacquet River (120 miles) and the Margaree (200 miles). At least one salmon liberated as a smolt in Maine has been angled in an east coast Newfoundland river (A. Meister, personal communication).

Some salmon originating in Gulf of St. Lawrence rivers are taken in commercial fisheries along the Atlantic coast of Nova Scotia and as far around as the head of the Bay of Fundy. In general, tagged hatchery smolts have shown distribution patterns at recapture similar to those of tagged wild smolts from the stream in which they were liberated. There is urgent need for a better understanding of the marine phase of salmon biology and population dynamics.

Ascent of rivers. Perceptive Canadian studies of salmon entry into rivers and their use by anglers have been published by Hayes (1948, 1953) and Huntsman (1939, 1962). Entry early in the season appears to have some relation to warming of the sea water, at Margaree (in 1935,1936) a sea temperature of 40-45°F (5-7°C) appearing to be related to first appearance of salmon on the coast. Entry and ascent of rivers is greatly affected by river discharge as well as river temperatures. Changes in discharge, particularly freshets and especially decline in freshet flow, even when produced by manipulation of discharge from dams (Hayes, 1953; Huntsman, 19 ; SA '63/E-25) favour salmon entry and their being caught by anglers. Tide and wind conditions also affect entry into rivers, appropriate conditions being different for different streams. A factor which recently appears to be emerging as important for time of entry is the nature of the stock (Saunders, 1967) including its genetic characteristics (SA '64/18; SA '66/E-13; SA '67/10).

Additional observations pertinent to salmon movements and migration recorded through the St. Andrews Station follow.

For hatchery-reared smolts a safe standard of size for spring liberation is about 15 cm (6 inches). For maximum seaward migration, liberation of such stocks should be during the normal period of smolt migration for the stream under consideration -- generally late May and early June. Earlier or later liberation will result in a noticeably lower percentage of migrants and increased mortality for those failing to migrate (SA '59-60/160).

Studies of smolt passage at dams were made on the Pollett River in 1958 and 1959. Earlier studies on behaviour of young salmon in turbulent currents (Elson, 1937) contribute to understanding behaviour unfavourable to migration at dams. Migrating smolts tend to move or be carried in the direction of water flow. They also tend, like other salmon, to head into and even swim against strong, turbulent and especially accelerating current. Greatly accelerating current as at the crest of a dam overflow (or rapids) results in a tendency to swim upstream and away from such stimulus, as Saunders (1960) has also observed. Decreasing the rate of acceleration, as by providing a long, gently sloping spillway, encouraged downstream passage. Plunging currents, if strong, resulted in orientation against the current, i.e. towards the surface. Such behaviour provides one explanation for a tendency of smolts to be delayed in head-gate wells of dams where they may rise either against a plunging, turbulent current of moderate strength, or be carried in the violently upwelling current sometimes found between gates and rear walls of the well. Imprisoning was accompanied by serious emaciation of many smolts delayed at the Beechwood dam, Saint John River, N.B. (SA'58/153; SA'59/168; SA'60/181). Delay occurring in head-ponds can result in loss of a high proportion of migrating young, sometimes 70% or more (Saunders, 1960).

Upper reaches of the 70-mile long Northwest Miramichi produced proportionably more early-run grilse than the lower reaches, as found by smolt tagging and grilse counting operations at two levels on the river. The sequence of events seemed to be: (1) cool headwaters produce slowly grown 3- and 4-year smolts, large enough to migrate early in the season and returning as early grilse; (2) warm lower reaches produce fast grown 2-year smolts which complete their pre-smolt growth in the season of descent, hence descend late, these returning as late grilse.

When criterion for early-run (versus late-run) was capture in fresh water several miles above tide head before mid August, smolts of early-run parentage returned mostly as early-run grilse or salmon while late-run progeny (parents taken in estuary in September or later) were taken in fresh water mostly in September or later (SA'64/18; SA'66/E-13; SA'67/10).

3.52 Schooling. Until they attain the smolt stage, young salmon in streams have seldom been observed schooling. This is to be expected in view of their tendency to establish individual home territories. But parr in large pools have been observed travelling in small schools, or sometimes in association with schools of other, perhaps mixed, species including minnows and suckers. Under conditions of high river temperature (over about 25°C), when parr may accumulate in cool spring outflows, Elson has observed schools of 100-200 parr in such outflows, but such schools dissipated as temperatures moderated.

Smolts moving downstream commonly accumulate in schools of a few to hundreds of fish.

To what extent such schooling may continue in the ocean is unknown. But fishermen often take several fish of almost identical size in their nets at one time. Fishermen at the upper end of the Bay of Fundy say that they often see August post-smolts in schools of 50 or more, grilse in groups of about 10, and large salmon in groups of 2-5 (F. Watson, personal communication). "Runs" of salmon entering rivers within a short period of time may or may not be indicative of schooling habits. Commercial fishermen speak of having a school of salmon striking their nets. No good data on the importance of schooling in Atlantic salmon have been published and we are not aware of any systematic studies on this matter.

3.53 Responses to stimuli

Quite a bit of work has been done on responses of salmon of various stages to stimuli. This is summarized briefly, under headings provided in the FAO Synopsis form.

3.531 Mechanical. Responses of salmon to water currents have already been mentioned. A key factor appears to be change in rate of flow. Huntsman (1962) describes how salmon in the narrow channel of an estuary, with strong currents at certain stages of the tide, behaved somewhat similarly to salmon in a stream. Hayes (1953) concluded that daily increasing differences in tidal amplitude seemed to be effective in concentrating salmon in an estuary and initiating entry into fresh water. Elson (1937) studied parr behaviour in relation to current flow, especially turbulent patterns of flow and changes in rate of flow. By manipulating changes in flow, parr could frequently be induced to move up- or downstream. Stuart (1962) found that a standing wave often stimulates salmon to jump. He believed this to be associated with supersonic vibrations produced by internal friction of the water (1964). Additional studies of behavioural responses, at all stages of life history, to different patterns of current flow, including turbulences, should contribute to better understanding of the migratory movements of salmon, passage at obstructions, etc.

3.532 Chemical. Entry of salmon from the sea into rivers involves passage through salinity gradients. While the probable importance of such gradients has been recognized, we are aware of no detailed studies on responses to such by Atlantic salmon. It is supposed that entry into natal rivers involves chemical discrimination of natal river fresh water. Again, we are not acquainted with specific studies on Atlantic salmon. In recent Margaree experiments, hatchery smolts of other river origin were held for 3 days in the hatchery fed by a brook drawing water from gypsum pot-holes and having high electrical conductivity. Those fish reported returning to the system were taken in the river below the brook and in the brook, but none in the less conductive main river water above the brook. Summer temperature of the brook is also often more than 5°C below that of the main river. Sensitivity of salmon, both young and adult, to copper and zinc ions, which salmon avoid, in both stream and laboratory water has been described in several papers by Sprague with co-authors (references given earlier). Sprague has also studied responses to other forms of pollutants.

Low pH (4.0 or below) associated with freshets, in a stream running through both bog area and a geological formation containing iron pyrites, resulted in downstream movement of underyearling parr and even death when they were held in cages. Fish from a less acid stream were more sensitive than those from an acid stream (Elson, 1940, 1942).

When given a choice of water in the stream at pH 5.9 and 18.5°C, mentioned above, versus water from a bank-side spring pool containing much decaying vegetable matter at pH 5.1 and 17.0°C, underyearling parr avoided the spring water which contained some factor, perhaps methane, quickly lethal to young salmon but not to trout of similar size. The factor causing avoidance was not low pH of itself, for when, during a freshet, pH in the brook dropped to 4.0 but in the spring water to only 4.5, young salmon still avoided the spring water (Elson, 1940).

3.533 Temperature plays an important role in salmon behaviour. Lethal limits as reported by Huntsman (1946) for fish which had some degree of natural acclimation were, for very small parr nearly 34°C, for larger parr nearly 33°C, and for adult salmon about 28 or 29°C. Adult salmon in fresh water become comparatively inactive at temperatures above about 21°C. Fisher and Elson found that underyearling and larger parr, acclimated for 1 month at 4°C, when given choice in a gradient, stayed mostly in water at about 14-16°C and that they showed maximum response, by swimming, to an electrical stimulus at about the same temperature.

Elson (1962) and White (1940), among others, have reported a strong relationship between smolt migration and water temperature; both found massive seaward movement occurred as temperatures rose to and above about 10°C.

While Huntsman (1939) found that rising sea temperature was associated with timing of first entry of salmon in early summer, Hayes (1953) concluded that sea temperature had little effect in initiating separate summer runs of fish. Data for analysis of water conditions associated with entry of salmon into the Northwest Miramichi are extensive, but analysis has not yet been completed.

Spawning would appear to be associated with a drop in water temperature from late summer levels to below 5-10°C, but we know of no definite studies on this matter.

3.534 Light. (Smolts and adults) (White, 1940; Hayes, 1963). Under certain conditions parr show a negative response to light which is proportional to the size of the fish. In pools the largest fish have been found deepest. With decreasing light intensity, first the smaller then the larger fish rise nearer the surface (Elson, 1937; Huntsman, 1945). Nevertheless, under other circumstances, parr may be seen holding position in bright sunlight, often under riffled surface current, when there is shade or cover under stones within a few inches of them (Elson, 1942). In this behaviour, Gibson (1966) and Gibson and Keenleyside (1966) found parr much more tolerant of bright sunlight than speckled trout. With submerged cover available, salmon parr were strongly photo-positive. Moving shadows cast over them will, however, cause parr to dart for cover under deeper riffles, stones, or other shelter. Parr will feed in complete darkness but normal periods of feeding are in the morning and afternoon. Strong light, as at mid day, may depress feeding activity somewhat (Hoar, 1942). It is probable that under extremely warm conditions (about 28° C ?) the sensitivity of parr to light is diminished, as with other fish species living in the same environment (Andrews, 195). Elson has observed parr in open, shallow, slow-moving water under such conditions, although as the water cooled later in the day, or if the parr succeeded in reaching a cool spring seepage, there they moved into places where they were less visible from above.

Both smolts and adult salmon make most of their down- and upstream migrations under conditions of comparatively low light (Hayes, 1953; White, 1940). None the less, salmon at both these stages are not infrequently seen "on the move" during bright daylight hours. Smolts, particularly when moving under the influence of rising temperature and in the absence of freshets, are commonly seen working their way downstream in schools by mid afternoon of a warm spring day.

3.535 Biological stimuli (inter- and intraspecific) relationships. Territoriality in parr has been well established by a number of authors. Keenleyside (1957) and Keenleyside and Yamamoto (1962) describe threat postures and behaviour involved in maintaining territoriality. Symons (SA'67/9) is studying interrelations of food and aggressive territorial behaviour on population densities of parr under stream conditions. With insufficient food the less aggressive, though not necessarily the smallest, fish emigrated from his experimental area first.

H.C. White (personal communication) has observed that in a salmon stream subjected to intensive predation by fish-eating birds, remaining parr are often found to maintain their home under rocks or other cover, contrary to normal behaviour in respect to light (Section 3.534). This behaviour is evidenced by the expanded condition of skin melanophores giving an almost black appearance to most parr seen in such streams. Elson has observed the same thing under similar conditions. A. Meister (personal communication) found that parr in an experimental stream after being exposed to attack by a king-fisher so altered their behaviour patterns, even when the bird was absent for days, that the fish could not be used for planned studies of behaviour.

Parr may live in close association with potential predators, as larger trout and eels, without showing tendency to avoid them unless the predator makes a sudden threatening motion (Elson, 1942; White, 1939; and unpub. observation by Elson).

3.536 Electrical stimuli. Fishing with the aid of electric current has been a common research practice for more than 20 years. Direct current from a portable motor generator has been used in salmon researches out of St. Andrews since 1949 (Smith and Elson, 1950). Elson (1950) states that 1 to 2 volts per inch of body length, in the Pollett River (resistance 25,000-35,000 ohms/cm^3), gave stimulus to movement for smaller fish and frequent stunning of fish over 5 inches (12.5 cm) in length. Fisher and Elson (1950) using electrical stimulus to study temperature-activity responses of salmon and speckled trout in apparatus similar to that used by Elson (1942) found that the minimum electrical stimulus, applied by condenser discharge, to produce a response in 10-cm parr, was between 40 and 80 volts in a 4-ft long trough, i.e. about 0.6-1.2 volts/inch, and that an electrical gradient of about 1-4 volts per inch was required to produce maximum response. Highest stimulus was required at lowest temperature (1.8° C) and minimum stimulus at temperature near the preferred temperature (14-16°C) of the fish. Variation in response to electrical current under different temperature conditions is commonly observed in electrofishing.

While a-c current, including that from an induction coil produces no orientation, steady d-c current results in movement towards the positive pole (anode) or, if of sufficient strength (i.e. gradient) produces electronarcosis. Recently, pulsed d-c having a discharge of square wave pattern has been much used. If pulse times and voltages are appropriately balanced to the physiological conditions of fish, this method produces stronger galvanotactic responses from fish with minimum chances of narcosis or of injury to them (e.g. Patten and Gillespie, 1966).

Practically all writers on electrofishing caution, rightly, against the potential hazard to operators.

Electric current has been used for guiding migrating Pacific salmon and, in Europe, for preventing Atlantic salmon from swimming upstream into power-house tail races. Its use for guiding downstream migrants has not, as far as we know, been accompanied by wide success (Lethlean, 1953).

3.537 Variations in reactions to stimuli. Foregoing sections have dealt with some of the variations in reactions to stimuli resulting from changes in temperature, change in physiological state accompanying growth and maturation, etc.

Little discussed so far, and of particular interest now when rapid industrialization is changing many salmon waters, are the sublethal effects of contaminants man discharges directly or indirectly into waters. Avoidance of natal stream because of base metal pollution has been mentioned and is but one case.

Ogilvie and Anderson (1965) showed that subjecting young salmon to sublethal doses of the chlorinated hydrocarbon pesticide DDT, upset temperature reactions of the treated parr by, for 17°C acclimated fish exposed to 40 ppb DDT, increasing the selected temperature as much as 10°C. Such changes in normal response could have drastically bad effects on populations of young in warm streams. J.M. Anderson (personal communication) has guided other, as yet unpublished, research showing deleterious changes in physiological responses, and even in learning, when young Atlantic salmon are exposed to certain present day stream pollutants.

Below are listed some additional FRB Atlantic salmon research results. Time does not permit fitting them into a framework of work done elsewhere. The FAO format, however, is continued.

4. Populations.

4.1 Structure.

4.11 Sex ratios. Some discussion of this has already been provided.

4.12 Age composition.

4.121 Age composition of the population as a whole.

4.122 Age distribution of the catch.

4.123 Variations with place and season.

4.124 Age at first capture. Though little has been written on the matter, large parr and smolts are extensively utilized by anglers seeking small trout in many streams.

4.125 Age at maturity. With similar food and temperature, more (70%) post-smolts matured in 1½ years in fresh and brackish water than in full salt (only 40%) (SA '67/12).

4.126 Maximum age.

4.127 Density of age groups.

4.13 Size composition.

4.2 Abundance and density.

4.21 Estimation of population size. Admitting crude basis for his computations, Elson (1957) estimated that Maritime salmon streams at that time received annual natural stocking at a rate of about 80 million late-summer underyearlings per year. Assuming moderately favourable conditions, adult stocks were estimated at ½ to 1½ million salmon per year. Fisheries were estimated to use about ¼ of the stock. In 1967 commercial catches for the area were reported as about 1.7 million lb or the equivalent of 150-200 thousand salmon with probably less than 100 thousand additional fish to anglers (80,274 recorded). With recent industrial developments, including pollution, and hydroelectric developments on salmon streams, conditions are probably less favourable than 10 years ago.

Commercial catches in Newfoundland have, as in the Maritimes, increased during the last 10 years. In 1967 they amounted to 4 million lb. Many of the salmon are of Maritime and Quebec origin (Bergeron, 1959; Kerswill, 1955, and in preparation; Murray, in preparation). Angling catch in Newfoundland usually takes less than half as many fish as in the Maritimes where about 2/3 of the sport catch are grilse, and over 90% of salmon angled in Newfoundland are grilse. There seems little reason to believe total Canadian stocks would be much more than double those of the Maritimes; they would probably lie between 2 and 4 million adult salmon. This estimate should not be used to conclude that present exploitation rates are either low or high, but rather as an indication that stocks have a finite, not very large limit.

4.22 Changes in abundance. Fluctuations in abundance of Atlantic salmon as measured by year-to-year commercial catches vary by a ratio of about 1:5. They have been discussed by Huntsman (1931) and Kerswill (1959), among others. Both Elson (1957) and Huntsman (1931) have pointed out a lack of apparent relation between abundance of year-classes of parents and progeny in catches.

Information on time and size of adult runs into the Miramichi, in relation to environmental conditions and fishery regulations, was obtained by operating a sampling trap in the estuary and counting fences on large tributaries throughout most of the open-water season for over 15 years. Adult populations can also be related to estimates of young made by counting parr in the same sample areas year after year. Evidence is accumulating that the effect of commercial fishing on angling has not been large, on the whole, but it may impinge heavily on angling for stocks of early-run large salmon. In recent years there has been a great increase in the proportion of grilse entering the system and a substantial run of large salmon entering in autumn has greatly diminished, in fact almost disappeared from the Northwest Miramichi River. As found by Hayes on the Margaree and LaHave (1948, 1953) and Huntsman on the Margaree (1939), all kinds of fishing in the Miramichi system benefited from frequent freshets (based on SA '62/F-3 to F-13).

4.23 Average densities, including annual mean density and density of adult females.

4.24 Changes in density.

4.241 Landings per unit of fishing effort. Allen (1967) has assembled available data on landings from Maritime fishery districts, including amount of gear used. These have been assembled and reproduced by IBM tabulation, including, when data were occasionally available, average weights of individual fish and average weights of catch per unit of gear, by month and yearly totals, from 1949 to 1965. A conspicuous feature in respect to size of fish is that frequently those taken early in the season are substantially larger than fish taken later. There is also considerable variation in average size of fish from one district to another and sometimes from year to year.

4.242 Variations with depth. Although occasional salmon have been reported taken from 100 ft or so when handlining or using trawl-lines for cod, all licensed commercial fishing is done with surface nets, whether shore-based or drifting. Drifters in both Canada and Greenland report nearly all fish taken in the upper 2 or 3 m of water; most such fishing is from dusk to dawn. Occasional catches are made by trawlers, especially in the Greenland area (Nielsen, 1961).

4.243 Seasonal variations in available stock. Some districts yield better catches early in the season, others later. June and July yield the largest catches in many areas. Relations between commercial catches and time of river entry require further study. Tagging experiments of Belding and Prefontaine (1937, 1938) and Huntsman (1939) showed tagged fish from June and July fishing recaptured in rivers only late in the season -- mostly in September. This would seem to indicate that commercial fishing utilizes late-run stocks. St. Andrews work in tagging hatchery-reared smolts of early versus late parentage showed substantial use of both in commercial fisheries, with perhaps greater use of early than of late stocks. Data are still accumulating.

4.3 Natality and recruitment.

4.31 Reproduction rates. Some experiments on the Pollett were directed towards finding optimum reproduction rates in a 10-mile length of river. Spawning stock was controlled from under 100 to almost 1400 parents. Survival rates of the progeny were followed year by year to the descending smolt stage. Comparable data were obtained to that for light, medium, and heavy plantings of hatchery-reared underyearlings. The observed maximum capacity for smolts was about 5/100 yd². This required about 45 lb of female salmon per mile of stream 10 yd wide. From these and studies of survival of young on other streams, a requirement of 70 lb of females for the same area was estimated where 3-year rather than 2-year smolts are produced. The above requirements allow for about 25% removal by angling, poaching, etc. (Elson, 1957, 1962).

4.32 Factors affecting reproduction.

4.33 Recruitment -- mean to fishable stocks, factors determining this and seasonal patterns of recruitment. Kerswill (in preparation) reports total returns of about 1.5% from over 273,000 fin-clipped smolts liberated in Miramichi streams and estimates total survival at about 5%. One third of the total catch of marked fish was made by Newfoundland nets. Total Miramichi smolt production was estimated at 2 million in the mid fifties, but lower from then to about 1961. Murray (1967) estimated 2.3% of Little Codroy smolts survived to become adults, 1.4% being taken in commercial fisheries and 0.9% returning to rivers. Most, but not all, returned to the natal stream.

4.4 Mortality and morbidity. Some causes of damage and mortality to adult salmon have already been discussed, as have parasites, etc.

4.5 Dynamics of population (as a whole). Little attempt has been made to construct mathematical models for Atlantic salmon populations.

Life-history readings have been made from scales of all fin-clipped adults from Miramichi studies to about 1962. This will provide some of the bases for later attempts to study population dynamics of Miramichi salmon.

4.6 The population in the community and ecosystem. Most material which could appropriately be listed here has been mentioned elsewhere and will not be re-set into this context now.

5. Exploitation

Much has been given above and will not be reorganized for this heading now.

6. Protection and management

6.1 Regulatory measures. Since Confederation increasingly strict regulatory measures have been applied to Atlantic salmon fisheries. It cannot be demonstrated that most of these have biological import for conservation (= best use) of the species. An example is restriction of netting in the Moisie estuary in 1859, quoted by Huntsman (1939). Improved fishing followed, in about 15 years, but appeared to be associated with fluctuations in catches elsewhere, and did decline when they did. The general history appears to be one of added restriction when periodic scarcities occurred. Such periods were automatically followed by improvements which were, locally, attributed to the local action. In the late 1950's and early 1960's a federal committee of scientists and administrators, whose duties involved them professionally with Atlantic salmon, drew up a set of guide lines, based on recognized biological findings, for Atlantic salmon regulations. Implementation has been delayed however and established sociological and traditional bases still form a large part of the foundation for Canadian Atlantic salmon regulations.

6.2 Manipulation of the environment -- physical.

6.21 Regulation of flow. Hayes (1953) and Huntsman (1948) have studied effectiveness of artificial freshets for bringing salmon into streams. Such controlled discharges are capable of stimulating upstream movement of salmon near or in a river but have little value for moving fish not already within the sphere of river influence. Elson (1940) found that distribution of parr in a small stream was also affected by small controlled increases in discharge, the young fish tending to move upstream a short distance.

6.22 Control of water levels.

6.23 Control of erosion and silting.

6.24 Fishways at natural and artificial obstructions. Many Newfoundland rivers have natural obstructions to upward movement of salmon (Blair, 1943). Early attempts to extend salmon rearing ground by providing passage over such obstacles had partial success and the work continues under the Resource Development Service of the Department of Fisheries (Murray, 1967).

Provision of fish-passes to permit ascent over man-made obstacles has been a long established management procedure in Canada. It is regarded primarily as an engineering problem and but limited scientific attention has been given to behavioural aspects of Atlantic salmon passage into and through fishways. Files in St. Andrews contain some unpublished data on value of different types of fishway orifices for salmon entry. Meaningful data were collected through the joint efforts of RDS and FRB staffs. Orifices into a fish-gathering gallery were most effective when near an operating turbine discharge.

Problems of smolt descent at dams received limited attention (SA '58/153; SA '59/168; SA '60/181).

6.25 Fish screens. The only Canadian work we know of involves an attempt, by RDS, to adapt louvres, successful in guiding young downstream migrants of Pacific salmon (Ruggles and Ryan, 1964) for guiding Atlantic salmon smolts. Results are still accumulating.

6.26 Improvement of spawning grounds. White (1942) describes a simple method of providing limited spawning beds where they are naturally lacking. These can easily be well scattered over potential rearing areas to assure useful distribution of young. Recent RDS studies (various references in Trade News and Fisheries of Canada) have involved provision of extensive artificial spawning beds limited to one part of a stream. While hatching has been successful, methods of making best use of the product have still to be worked out.

6.27 Habitat improvement. Cox (1945, 1946) found that provision of well scattered cover would increase the parr-holding capacity of a stream. Saunders and Smith (1962) found that stream alteration by concentrating currents in certain areas, as well as provision of structures giving added cover could alter the habitat in favour of trout rather than parr. Presumably manipulation could be devised to tip the balance in favour of parr, which favour rapids in contrast to pools if trout are present.

6.3 Manipulation of the environment -- chemical.

6.31 Water pollution control. Pollution of a stream having salmon and speckled trout with an agricultural fungicide (bisodiumethylene bisbithiocarbamate + zinc sulphate) killed some fish and caused others to move, in a moribund condition, as much as 8 miles downstream and into salt water. Populations were greatly reduced until replenishment by new year-classes (SA '64/50).

Some control of adverse effects of forest spraying on young salmon was achieved by reduction of DDT dosage, whether through lowered concentrations in applied spray or by substitution of less-toxic-to-fish insecticides along streams. Insecticides less damaging to fish but acceptable for forest conservation are being sought (Elson and Kerswill, 1967; SA '66/F-18).

Although DDT disappeared from salmon parr from a sprayed stream within 2 years, derivatives such as DDE declined only gradually during 12 years (SA '67/13).

Studies are being made of toxicity to salmon of kraft-mill effluent (SA '66/F-2).

Copper-zinc pollution in a stream causes avoidance by adult salmon and death of young (Sprague et al., 1965; Saunders and Sprague, 1967). Recent research shows that lethal action can be eliminated by use of the sequestrant NTA, but this does not eliminate problems of avoidance (SA '67/13).

Zinc is more toxic to young salmon at 5°C than at 17°C (SA '67/13), i.e. excessive concentrations in a stream in winter are even more deleterious than in summer. Despite several years of attempt to control copper-zinc effluent from a mine affecting the Northwest Miramichi, the problem still remains that toxic levels sufficient to kill fish are reached several times a year.

6.4 Manipulation of the environment -- biological.

6.41 Control of predation and competition. Work on effects of predation by mergansers and kingfishers on young salmon populations, and its control, is summarized in Elson (1962). Control of mergansers can increase smolt production from streams by as much as five times. Predation by kingfishers may be relatively unimportant and control is of doubtful value except in special cases.

Increasing smolt production by such means may not, however, have a very noticeable and direct effect on fisheries if environmental factors, e.g. river discharge, governing approach of salmon to fishery areas work strongly and adversely (SA '66/E-8; SA '67/9).

Other predators on Atlantic salmon in Canada have received consideration but none seem as important as mergansers (White, 1939).

The eel, in some streams, is both a predator on and competitor with young salmon. Predation may begin on the alevin in the redd (Elson, 1940a, b, c, 1941, 1957; Godfrey, 1956; SA '40 to '54/various summary reports).

6.45 Population manipulation. Planting and natural spawning experiments on the Pollett, Margaree, and Miramichi Rivers have indicated that certain stocks may be more amenable to use in certain fisheries than other stocks. Return rates to the Pollett were several times higher from native than from introduced under-yearlings (SA '62/F-8). In the Margaree and Miramichi, experiments involving introduced hatchery smolt returns from different batches of smolts in the same years were quite variable. Size at liberation and stock origin have recently appeared to be factors affecting returns (SA '66/E-16). That they are not the sole factors is indicated by the result of the Apple River experiment in which fish of early-run stock were introduced into a late-run river and returned as late-run grilse (White and Huntsman, 1938).

6.5 Artificial stocking.

Planting procedure, especially patterns of liberation, to get best smolt production was studied on the Pollett River. Results of early studies are given in Elson's report on predator-prey relationships, Part I (1962). Because of limited natural dispersal after planting, liberations should, if possible, be not more than about 2 miles apart. With uncontrolled bird predation, production was limited to rates between 0.2 and 1.1 smolts/100 sq yd of stream bottom. In small brooks where predation by birds was not important, production was at the rate of 3.3 smolts/100 sq yd. About 10-20 hatchery underyearlings/100 sq yd were sufficient to give such production. But with mergansers under control in a medium-sized river, plantings at the rate of 35 (for streams with mostly 2-year smolts) to 55 (for streams with mostly 3-year smolts) were estimated to be capable of giving 5-6 smolts/100 sq yd.

6.51 Maintenance stocking. With the basic information above, experiments involving introduction of hatchery-reared underyearlings to reinforce deficient native populations were undertaken. Procedural steps were: (1) assessment of density of native populations; (2) computation of number of additional parr which, based on observations of populations from sufficient and over-seeding, the stream could accommodate; (3) allowance for early post-planting mortality; (4) liberation of appropriate number of young at appropriate intervals along the stream. An allowance of 5 hatchery underyearlings for each deficiency of 1 wild underyearling (i.e. post-planting mortality of 80%) was sufficient to yield smolts at the estimated maximum rate of 5-6 smolts/100 sq yd. It is to be noted that seeding for maximum production of 6 smolts/100 sq yd may, in years of low pre-smolt to smolt survival, result in a production rate of only 3 smolts/100 sq yd (SA'60/163).

Plantings of well transformed smolts in the Pollett, Miramichi, and Margaree have given returns of adults, showing that even with full production of native smolts from a stream, stocks can be increased by use of hatchery-reared smolts liberated at normal seasons of smolt descent. Such increase is not possible when parr still in the river-dwelling phase are added to already sufficient native stocks.

When river-dwelling stages of parr are liberated, whether underyearlings or late autumn pre-smolts, or some intermediate stage, no increase in survival pertained whether fish were liberated at one point or dispersed manually over about ½ mile of stream, each liberation being sufficient in numbers of fish to fully stock the adjacent 2 miles of stream. With little predation by mergansers or fish, similar survival rates to the smolt stage were obtained whether underyearlings or pre-smolts were liberated, in autumn.

Hatchery-grown, pre-smolt and post-smolt parr liberated in autumn neither grow nor survive well to migrate as smolts the next spring. Hatchery-grown smolts liberated 10-30 miles upstream within 2 weeks of the peak of natural smolt migration can yield over 75% migrating smolts (SA'59/158; SA'60/162; SA'64/10).

6.52 Transplantation and introduction. Comments above are based on initial experiments involving introductions to areas not previously supporting salmon, because of barriers to adults. Experiments involving numbers of spawners required for maximum production from the Pollett involved, by 1957, transport of up to 1,000 adults from other branches of the Petitcodiac system. The introduced fish spread thoroughly and spawned widely over available reaches. As checked at a counting fence at the lower end of the experimental area, and by observation of fish and redds in the river, most spreading was in an upstream direction. In another experiment, daylight liberation of near gravid adults at a holding pool was followed by upstream spread of 3/4 of the liberated fish, but liberation in a shallow, swift rapid was followed by downstream spreading of about 2/3 of the fish.

6.53 Selection of stocks for artificial stocking. Evidence is accumulating that selection of stocks used for artificial bolstering of salmon production has much bearing on the success of results.

Return rates of smolt-marked grilse to a river normally producing grilse were much higher when most of the smolts were of native stock than when a high proportion were derived from hatchery stock introduced as underyearlings but from mostly 2-sea-year parentage.

Stocks from early-run (criterion = entry into fresh water before mid August) parentage are used more heavily in some fisheries, especially angling, than stocks of late-run parentage, but late-run stocks do get substantial use in some commercial and sport fisheries. Large smolts (over 18 cm total length) appear to have a better return rate than small (under 17 cm). Progeny of grilse have returned mostly, but not all, as grilse and of virgin, large salmon as large salmon (SA'64/18; SA'66/E-13 and E-16; SA'67/10).

6.6 Research techniques.

Techniques for assessing stream-dwelling fish, especially young salmon, mostly using d-c electrofishing aids, have been developed to the point where they have contributed importantly to studies of population dynamics, etc. (e.g. Smith and Elson, 1950; Elson, 1962).

Methods for trapping and counting descending and ascending migrants have been developed and improved (e.g. White, 1939; Elson, 1962; Schofield, 1967; SA'64/11; SJ'63/66).

Marking of smolts by fin-clipping or by applying serially numbered tags can provide vital information about ultimate destiny of the marked fish. Fin-clipping was used in most such FRB St. Andrews studies until the late 1950's. Since 1960 there has been increasing use of tags. Initially the pattern of tags used closely resembled that developed in Sweden (Carlin, 1955); a modification involving substitution of polyethylene filament for stainless steel has some advantages and some disadvantages. Other patterns of attachment (Scarratt and Elson, 1965) have been devised and tested. In 1968, four different patterns of tags are being tested for usefulness on Northwest Miramichi wild smolts. To date, comparative results are somewhat variable, but the Swedish pattern using stainless steel attachment appears to give as reliable results as any, under a wide variety of conditions. It is also one of the most expensive to fabricate and apply (Carlin, 1967; SA'64/11).

When naturally-produced smolts were marked at a counting fence, there was a higher rate of return from fin-clipped (5.7%) than from tagged (3.6%) fish. Return rates from unmarked fish appeared to be still higher. At any given date, returning unmarked fish were about 2% longer than tagged fish; the fin-clipped fish were intermediate in size (Saunders and Allen, 1967).

7. Controlled rearing.

Aside from early development of artificial hatching and rearing techniques, beginning in Canada in the 1860's (MacCrimmon, 1965), the amount of systematic research, in Canada, on controlled rearing of salmon has been limited. But Canada developed, within less than half a century, one of the most, if not the most, extensive series of Atlantic salmon hatcheries in the world. Most fish were liberated within a few months of hatching. Value of the procedure was not subjected to critical assessment for many years. In the 30 years between 1930 and 1960, however, serious evaluation commenced. The Fisheries Research Board took little part in the early development of the system except to provide occasional assistance in pathological matters (e.g. M'Gonigle, 19). It did contribute to evaluation of the product and to search for more effective ways of using the product, beginning in the mid thirties.

More recent advances in Canadian artificial rearing techniques for Atlantic salmon have been based largely on research and developments in other countries, especially Sweden. Aside from basic studies in physiology, reported in earlier sections, systematic FRB research contributions in the area of controlled rearing are largely a matter for future consideration. Most efforts along this line of approach have been and are being made under the Resource Development Service of the Department of Fisheries. Material for review is not readily available at this time.

OFFICE MEMO

TO: Date

Schaffer, W. M. & P. F. Elson. 1975. The

FROM: adaptive significance of variations in life history

SUBJECT: among local populations of Atlantic salmon in

REMARKS: North America. Ecology 56(3): 577-590.

Increase age at maturity asc. w/ distance & difficulty to spawn (longer & more difficult - older the fish). Commercial fishing selects against larger, older fish. - alters genotypes. - Rapid sea growth delays maturation, slower growth = earlier maturation.

25

Transferrin Polymorphism in Atlantic Salmon (*Salmo salar*)

DAG MØLLER

Fisheries Research Board of Canada
Biological Station, St. Andrews, N.B.

MØLLER, D. 1970. Transferrin polymorphism in Atlantic salmon (*Salmo salar*). J. Fish. Res. Bd. Canada 27: 1617–1625.

Three main patterns of transferrins, made up of two molecular types, were found by starch–agar electrophoresis in plasma of hatchery and wild Atlantic salmon (*Salmo salar*).

Distributions of the observed patterns from progenies of three hatchery matings agreed with expected Mendelian distributions in offspring of known parentage, implying that the bands have their origin in two codominant alleles. In nearly all samples of the wild salmon the genetic basis of transferrin variation was demonstrated by nonsignificant differences between observed and expected distributions when the Hardy–Weinberg formula was applied.

Frequencies of the Tf^A allele differed in samples from different rivers and within the same river; the Atlantic salmon forms genetically different populations. Interchange of stocks probably influenced the values of the different gene frequencies found.

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INTRODUCTION

THE PRESENCE OF transferrin, the serum protein that binds ferreous ions, in Atlantic salmon (*Salmo salar* L.) has been shown by electrophoresis and autoradiography (Møller and Naevdal, 1967), and polymorphism in the protein has been reported (Møller, 1970; Wilkins, 1969, 1970; see also de Ligny, 1969).

Transferrins have been useful for the identification of fish populations, particularly for those of cod (see Jamieson and Jonsson, 1970). Earlier investigators have indicated genetic diversity in salmon also (Nyman, 1966, 1967a, 1967b, 1970; see also de Ligny, 1969).

This report describes transferrin polymorphism in Atlantic salmon, discusses the genetic origin of the observed differences, and gives values of gene frequency in samples from different localities in eastern Canada and the United States.

MATERIAL AND METHODS

Plasma specimens sampled in 1969 were obtained from approximately 400 juvenile salmon (300 were hatchery fish) and 1600 grilse and large salmon (Table 1, Fig. 1). The hatchery fish came from three progenies, each from two parents only. Two progenies were kept together after one was marked by clipping the adipose fin; the third was kept separately. All the other specimens were from wild animals trapped in research counting fences or caught by nets for hatchery purposes. Individuals from 16 different localities ranging from Sand Hill River, Labrador, in the north, to Narraguagus River, Maine, in the south were represented in the material.

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TABLE 1. Localities from which salmon were obtained for plasma specimens, dates and methods of capture, life stages, and number of fish in 1969.

Sample	Locality	Date of capture	Gear	Life stage	No. fish
1	Sand Hill R., Labrador	July 23–29	Counting fence	Grilse	130
2	Adies Stream, Nfld.	Aug. 1	Counting fence	Grilse	112
3	Carleton, Que.	June 1–25	Trapnet	Large salmon	120
4	Restigouche R., N.B.	Sept. 2	Seine	Grilse & large salmon	120
5	Millbank, N.B.	July 24–29	Trapnet	Grilse & large salmon	59
6	Northwest Miramichi R., N.B.	May	Counting fence	Smolt	93
7	"	July 3–6	"	Grilse	117
8	"	July 17–29	"	Grilse	146
9	Southwest Miramichi R., N.B.	Sept.–Oct.	Trapnet	Grilse & large salmon	117
10	R. Philip, N.S.	July–Sept.	Fishway trap	"	120
11	Margaree R., N.S.	July–Sept.	Seine	"	95
12	Saint John R., N.B.	May–June	Fishway trap	"	105
13	"	July–Oct. 15	"	"	142
14	"	Oct. 16–31	"	"	91
15	Machias R., Maine	June–Sept.	Counting fence	"	32
16	Narraguagus R., Maine	June–Sept.	Counting fence	"	24
17	Margaree Hatchery, N.S.	Dec. 10		Parr	100
18	"	"		"	100
19	"	"		"	102

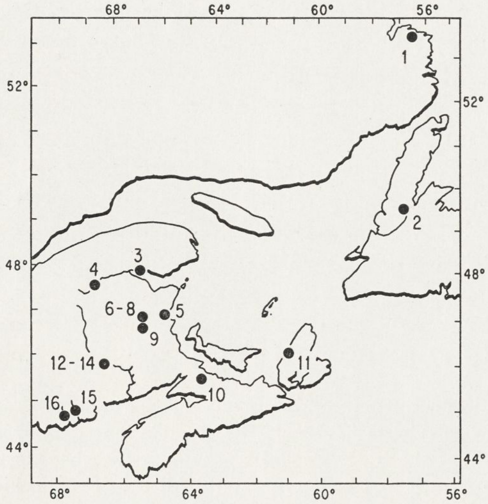

FIG. 1. Location of capture of the 16 wild samples.

The fish were anesthetized with tertiary amyl alcohol or M.S. 222-Sandoz before bleeding. Blood was drawn by cardiac puncture from grilse and large salmon and by cutting the tails of smaller fish. To prevent haemolysis, all samples were heparinized. The whole blood was kept cool during storage and transported to the laboratory where specimens were centrifuged. The plasma was pipetted off and analysed or put in a deep freeze for subsequent analyses.

The electrophoretic technique used was a modification of starch–agar gel electrophoresis on microscope slides (Sick, 1965; Møller, 1966). The buffer giving best separation of the transferrins was a tris (hydroxymethyl) amino methane (Tris) buffer modified after Aronsson and Grönwall (1957): 60.6 g Tris, 12.8 g boric acid, and 6.0 g ethylenediaminetetraacetic acid in 1 liter distilled water.

The *p*H of the buffer varied between 8.0 and 8.2. Control of *p*H at 8.1, the preferred level, was achieved by mixing two stock solutions, one with 40 g of boric acid instead of 12.8 g and the other with no boric acid.

The microscope slides were covered by 3 ml of gel, and after application of the sera specimens the gels were covered with a thin sheet of plastic.

Each electrophoretic run contained 20 specimens, two on each slide, and lasted for $5\frac{1}{2}$ hr with approximately 6 v/cm gel. After the run, the proteins were fixed in a 5:5:2 mixture of methanol, water, and glacial acetic acid, then stained with amido black 10B. The stain was then removed from the gel in the fixative and the gel was dried.

Centrifuging, pipetting specimens, and electrophoretic analysis were performed in a refrigerated room (–2 to +2 C). However, heat generation still made it necessary to have ice in the compartment underneath the slides.

Where the patterns were difficult to define, specimens were reanalysed, this time with only one specimen on a slide.

RESULTS

Patterns Found

Three common patterns of plasma proteins (Fig. 2) were found. Most of the individuals possessed a slow moving (i.e., anodic) component (1) in common. Next to this band all individuals had either one or both proteins 2 and 3. Still faster bands (4 and 5) were present in most animals.

Band 2 has been shown to bind ferreous ions (Møller and Naevdal, 1967). The difference in electrophoretic mobility between bands 2 and 3 is interpreted as phenotypic expression of codominant alleles. Three phenotypes were distinguished, Tf AA, Tf AC, and Tf CC, involving one or both of the bands Tf A (band 3) and Tf C (band 2).

Bands 1, 4, and 5 (Fig. 2) have not been identified. Both their occurrence and their intensity varied occasionally, and their presence could depend upon environmental factors. Blood samples with a high degree of haemolysis resulted in electropherograms showing haemoglobin patterns also. The haemoglobin pattern did not obscure the identification of bands 2 and 3.

Eight rare patterns in the transferrin region (Fig. 3, types 4–12) were also found. In types 4 and 5, Tf C and Tf A, respectively, are found together with a band with the same intensity as the transferrins. The band that has not been found alone had only slightly faster anodic mobility than Tf C. It is presumed to be another transferrin and it is therefore called Tf B. In routine analysis, however, it was difficult to distinguish Tf BC from Tf CC and Tf AB from Tf AC. When detected, therefore, the band was ignored and the patterns counted as Tf CC and Tf AC, respectively.

In the patterns 6–12 (Fig. 3), one or two faint bands are present together with Tf A or Tf C or both. One or these bands had a slower anodic mobility than all the other bands found in the transferrin region; the two others had the same mobility as Tf A and Tf C, respectively. These bands were very rare. The highest number of specimens found in one sample with one of these patterns was 3 out of 100. Types 6–10 were denoted Tf AC; type 11, Tf CC; and type 12, Tf AA.

The intensity of the bands varied. As a rule the one-band patterns were stronger than the two-band patterns, and in a very few Tf AC patterns, Tf C sometimes had a more pronounced appearance than Tf A. In some rare specimens where Tf A was weak, it was impossible to decide if the pattern was a real Tf AC or type 6 in Fig. 3.

The electrophoretic patterns were always distinct when using specimens up to about 1 week old. Frozen sera usually gave reliable results over several months, but repeated freezing and thawing affected the distinctness of the bands, first the weak ones and later the major patterns.

Distribution of Patterns in Hatchery Fish

The observed distributions (Table 2) of the three patterns Tf AA, Tf AC, and Tf CC in parr of the three progenies (samples 17, 18, and 19) are different. Only the major patterns were present, and the progenies appear to represent

Table. 2. Observed distributions of the transferrin patterns in hatchery samples and distributions expected on basis of presumed genes of parents.

	Observed				Expected		
Sample	Tf AA	Tf AC	Tf CC	Probable parents	Tf^A/Tf^A (homozygotes)	Tf^A/Tf^C (heterozygotes)	Tf^C/Tf^C (homozygotes
17	51	49		$Tf^A/Tf^A \times Tf^A/Tf^C$	50	50	
18	1	99		$Tf^A/Tf^A \times Tf^C/Tf^C$		100	
19	29	52	21	$Tf^A/Tf^C \times Tf^A/Tf^C$	25.5	51	25.5

three different crosses between the three genotypes of the two allele systems postulated above. In sample 18, however, a single individual had a Tf AA pattern, whereas all of the others had the Tf AC pattern. The parr of this sample were still available. A single fish in this sample had a clipped adipose fin, indicating that it came from a different pair of parents than the other fish; it was assumed that this individual gave the anomalous result.

The observed distributions were similar to the Mendelian distributions expected on the basis of the presumed genes of the parents (Table 2), and the two codominant alleles involved are called Tf^A and Tf^C.

Distribution of Patterns in Wild Fish and Comparison of Gene Frequencies from Different Localities

There is good agreement between observed and expected distributions in all samples of wild fish except those from the Miramichi River (samples 7

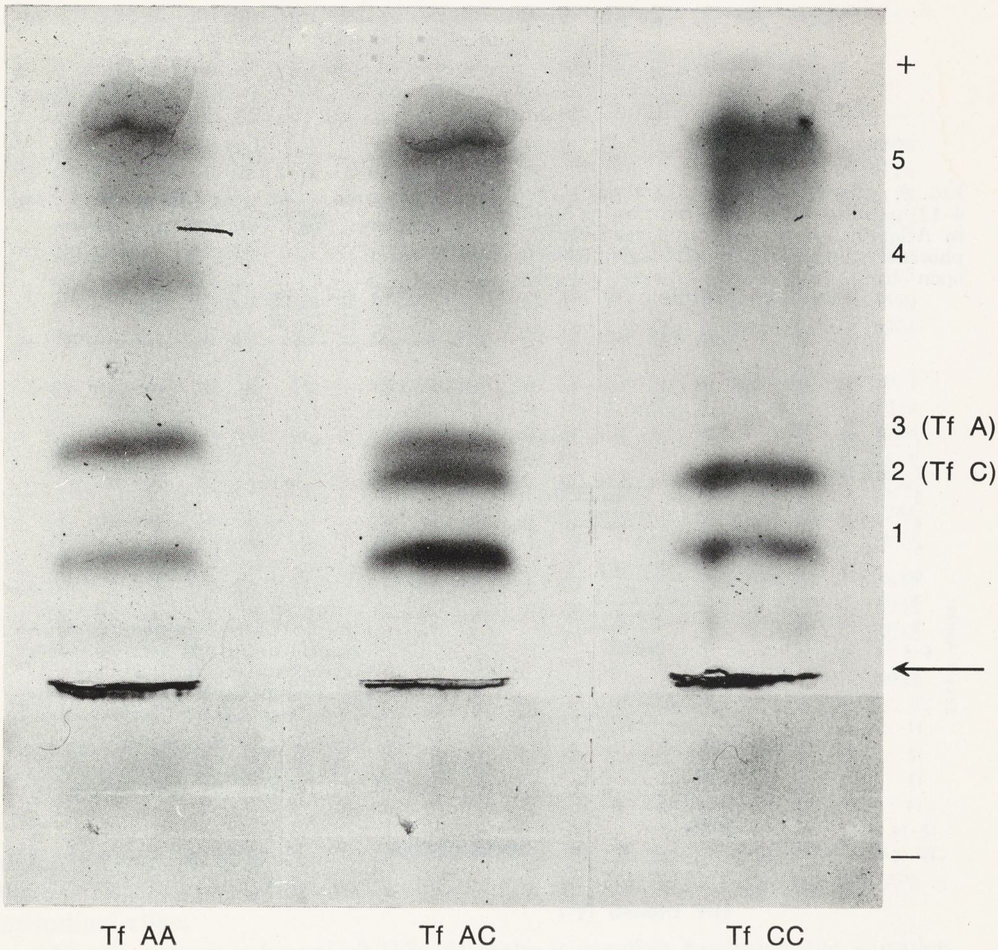

Fig. 2. Main plasma patterns found in Atlantic salmon by starch–agar electrophoresis. Bands 1, 4, and 5 are unidentified molecules; bands 2 and 3 are transferrins. Arrow indicates site of application.

FIG. 3. Common (types 1–3) and rare (types 4–12) patterns in the transferrin region found in Atlantic salmon by starch–agar electrophoresis. Solid bars, bands with high intensity; open bars, faint bands. Arrow indicates site of application.

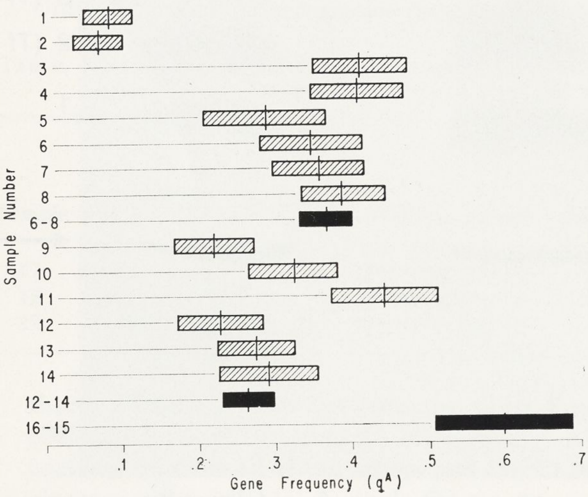

FIG. 4. Observed mean frequencies (vertical lines) and 95% confidence limits (horizontal bars) of Tf^A (q^A) in samples of wild fish. Sample areas as in Table 1.

8, and 9) and the subtotal of the samples (12, 13, and 14) from the Saint John River (Table 3). The frequency of the Tf^A allele varies greatly. The lowest value, 0.0714, is found in sample 2 from Adies Stream, Newfoundland; the

TABLE 3. Observed distributions of the transferrin patterns in the wild fish, distributions expected according to the Hardy–Weinberg law, and frequencies of the Tf^A allele (q^A).

	Tf AA		Tf AC		Tf CC				
Sample	Obs.[a]	Exp.[a]	Obs.	Exp.	Obs.	Exp.	χ^2	Probability of worse fit	q^A
1	2	0.93	18	20.14	110	108.94			.0846
2	1	0.57	14	14.85	97	96.57			.0714
3	22	20.42	55	58.16	43	41.42			.4125
4	21	20.01	56	57.98	43	42.01			.4083
5	7	4.90	20	24.20	32	29.90			.2881
6	11	11.36	43	42.29	39	39.35			.3495
7	22	15.08	40	53.84	55	48.07	7.7522	0.01–0.005	.3590
8	28	22.25	58	69.50	60	54.25	3.9983	0.05–0.025	.3904
6–8[b]	61	48.58	141	165.86	154	141.57	7.9728	0.01–0.005	.3694
9	10	5.78	32	40.44	75	70.78	5.0941	0.025–0.01	.2222
10	12	12.68	54	52.65	54	54.67			.3250
11	19	18.57	46	46.86	30	29.57			.4421
12	8	5.49	32	37.03	65	62.48			.2286
13	14	10.71	50	56.57	78	74.72			.2746
14	10	7.72	33	37.57	48	45.72			.2912
12–14[b]	32	23.70	115	131.60	191	182.70	5.3777	0.025–0.01	.2648
15	10	11.28	18	15.44	4	5.28			.5938
16	9	8.76	11	11.48	4	3.76			.6042
15–16[c]	19	20.04	29	26.92	8	9.04			.5982

[a]Obs. = observed; Exp. = expected.
[b]All three samples taken in the same locality.
[c]Samples from two neighbouring rivers.

highest value, 0.6042, is present in sample 16 from Narraguagus River, Maine. There is no indication (Table 3, Fig. 1) that this variation follows a latitudinal cline.

The frequency values of q^A (Fig. 4) make it possible to divide the samples into three different groups: samples 1 and 2 from Labrador and Newfoundland, samples 3–14 from New Brunswick and Nova Scotia, and samples 15–16 from Maine. A large area was unsampled between samples 2 and 3; the discontinuity between these two samples, therefore, is not surprising. This cannot apply to the second case, however, because the distance between the river mouths is only about 120 km and there are only about half a dozen salmon-producing streams in between.

In the second group, each of samples 6–8 differed from sample 9 in gene frequency ($P < 0.05$), and sample 11 from each of 12–14. Samples 6–8 were all from the Northwest Miramichi, and sample 9 from the Southwest Miramichi. Sample 5, from the estuary of the river, had a value intermediate between those for the two main branches.

DISCUSSION

Interpretation of Bands

The two bands called Tf A and Tf C (either one or both were present in all Atlantic salmon investigated) are well-defined in starch-agar electrophoresis. Although Tf C has ironbinding capacity (Møller and Naevdal, 1967), this has not been shown for Tf A. The distribution of the three patterns, Tf AA, Tf AC, and Tf CC, in hatchery as well as wild fish, however, proves that Tf A and Tf C are phenotypic expressions for two codominant alleles.

It has not been possible to test the band called Tf B. Both the position and the strength conform to the transferrin bands and the protein is interpreted, therefore, as a rare transferrin component.

For expediency in classification, a Tf B always was counted as a Tf C. In other words Tf B and Tf C were treated as one single character. This treatment will not have any influence on the observed and expected distributions of the two groups of characters, Tf A being one group and Tf B and Tf C being the other. This course of action, however, could cause some loss of the capability of the transferrin system in regard to identification of populations. Mutual differences in the number of Tf B and Tf C are not registered.

Questions have been raised concerning the interpretation of the weak bands (see Fig. 3, types 6–12) (Naevdal, 1968). The bands found in the same positions as Tf A and Tf B were counted as Tf A and Tf B, respectively. This was done preliminarily because of the position and secondly because of the few numbers of individuals with a Tf AC pattern with a weak Tf A band. However, the number of individuals with weak bands were too few to have any great influence upon the distributions of the transferrin patterns and the calculated gene frequencies.

Identification of Populations

Differences in gene frequency between groups of individuals of the same species and disparities between observed and expected distributions of phenotypes as a result of an excess of homozygotes are characteristics commonly used to identify genetically different Mendelian populations.

The variation of the frequency of the Tf^A allele reflects the genetic variability in Atlantic salmon. The similarity between the observed distributions and the expected distributions of the transferrin patterns and the similarity in gene frequencies at the same locality of smolt as well as adult salmon (Table 3, samples 6, 7, 8; 12, 13, 14) and between neighbouring localities (samples 3, 4; 15, 16) support the conclusion that the statistically significant differences found represent differences between populations.

Two groups of samples, those from the Miramichi River (Table 3, samples 7, 8, 9) and the combined samples from the Saint John River (samples 12, 13, 14) showed significant differences between the observed and the expected distributions of the transferrin patterns. The material is too limited for any final conclusion, but the excess of homozygotes in these rivers may signify the existence of different populations further upstream (Saunders, 1967).

Genetic variability has been shown before in other salmonids. Brannon (1967, 1969) and Raleigh (1967; MS, 1969) experimented with progeny of sockeye salmon (*Oncorhynchus nerka*) taken from parents spawning above and below lakes. The inlet and outlet fry differed significantly in their rheotactic and phototactic responses, and in both cases the rheotactic response resulted in a greater proportion of each population finding its way to its nursery lake. The fry were kept in a controlled environment from the time of fertilization until the final tests of behaviour, so that any differences must be assumed to be genetic in origin.

The present results for Atlantic salmon are, thus, in accordance with the general view that nearly all crossbreeding species are made up of genetically distinct populations.

Two questions can be raised, however. Over the years there has been a great amount of interchange of stocks within west Atlantic salmon that could have contributed greatly to the present heterogeneity. Most of these introductions have been of progenies from a relatively few parental fish that, by chance, could have had a quite different gene frequency from the parental stock. The influence of such interchange of stocks on the genetic diversity that was found cannot be ignored.

However, interchange of stocks can hardly explain all the observed genetic diversity. No recorded interchange of fish has occurred between either Sand Hill River (sample 1) or Humber River (sample 2) in the north, and any other river. The difference in gene frequency between these rivers and the rivers further south is probably of natural origin.

Nor can the stocking explain the observed pattern of distribution. If anything, frequent introductions would break down the isolation mechanisms and lead to panmixia (Calaprice, 1969), but this does not seem to have happened. The reason could be the common occurrence of the efficient homing instinct (Carlin, 1969; Ueda et al., 1967) or some other possible premating mechanisms.

Transplanting of stocks is likely to have had some influence on gene frequency, but the degree of this influence cannot be determined by the results of the present investigation. This problem could probably be solved by introduction of progeny with known gene frequency that differs markedly from the frequency in the recipient river (Møller and Naevdal, 1968), by identification and use of other genetic systems, or by extensive sampling and analysis of transferrin patterns, particularly in localities where no introduction has taken place.

The second question raised by the present results concerns maintenance of a polymorphic character in small populations. It has been postulated that genetic drift, "random fluctuations in gene frequencies in effectively small populations," will result in variation in the gene frequency from one generation to another, tending towards the homozygous state (Dobzhansky, 1951). If the migration of salmon individuals is severely restricted between spawning localities, as the present results suggest, the number of breeding individuals must be low in most salmon populations, and homozygosity could probably be a common occurrence. From this viewpoint, the kind of genetic diversity revealed in this study is unexpected; both alleles are well represented in all samples. This probably indicates the existence of homeostasis or balanced polymorphism in the Atlantic salmon. It is difficult at this stage to draw conclusions; more material has to be analysed, and efforts to estimate the number of breeding individuals should be made.

The existence of genetic diversity in Atlantic salmon cannot be denied; the investigation confirms the existence of populations that are clearly different genetically. However, interchanges of stocks may have affected the gene frequencies of the original populations but not have led to a general breakdown of the natural isolating mechanism. Genetically distinct groups of Atlantic salmon still exist.

ACKNOWLEDGMENTS

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Cytological and biochemical studies in back-crosses between the hybrid Atlantic salmon×sea trout and its parental species

AXEL NYGREN, LENNART NYMAN, KNUT SVENSSON and GUN JAHNKE

Department of Genetics and Plant Breeding, Royal Agricultural College of Sweden, Uppsala
Swedish Salmon Research Institute, Älvkarleby, Sweden

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A male hybrid between a female salmon from Lule river in Northern Sweden and a male trout from Ireland has been back-crossed to a female salmon and a female trout both from Lule river. Eleven months after the crosses had been made no offspring was left in the combination trout × hybrid, while 4 individuals of the combination salmon × hybrid were still alive. The chromosome numbers of the fish studied are: salmon, 2n = 58; trout, 2n = 80; hybrid, 2n = 69; back-crossed individuals 2n = 60, 64 and 66. Various proteins of the different components were analysed. To our knowledge this is the first joint cytological/electrophoretic investigation of hybrids of this salmonid combination.

Axel Nygren, Department of Genetics and Plant Breeding, Royal Agricultural College of Sweden, S-750 07 Uppsala 7, Sweden

During the preceding 100 years a few attempts have been made to bridge the gap between the Atlantic salmon (*Salmo salar* L.) and the sea trout (*S. trutta* L.) by artificial hybridization (e.g. DAY 1884; JONES 1947; ALM 1955). In early 1960, however, the very viable offspring of a female salmon grilse and a male sea trout hatched, and this event set off a whole series of hybridization experiments (PIGGINS 1965). Not only were these F_1 fish viable, but they also proved fertile and attained sexual maturity a year earlier than the parental species normally do. On top of that an F_2 generation was produced, again with low losses to early-feeding. The plasticity of the hybrid strain was tested by reciprocal back-crosses, and all four combinations yielded offspring with negligible losses (PIGGINS 1965).

None of these hybrid strains was analysed cytologically, but considerable chromosomal disturbances were to be expected due to the difference in chromosome number between the two species (SVÄRDSON 1945; NYGREN et al. 1968).

In 1965 an F_1 strain of landlocked salmon and trout was produced in Sweden, and the following year these fish were analyzed electrophoretically (NYMAN 1966). The true origin of the hybrids was evident from the protein patterns which were simple combinations of the parental patterns. This method thus displayed the feasibility of characterizing F_1 hybrids, and subsequent electrophoretic surveys of Piggins' Irish material were performed (HAEN and O'ROURKE 1968, 1969; NYMAN 1970). Due to the lack of cytological evidence several questions remained unanswered, but at any rate these investigations proved the presence of a true F_1 hybrid.

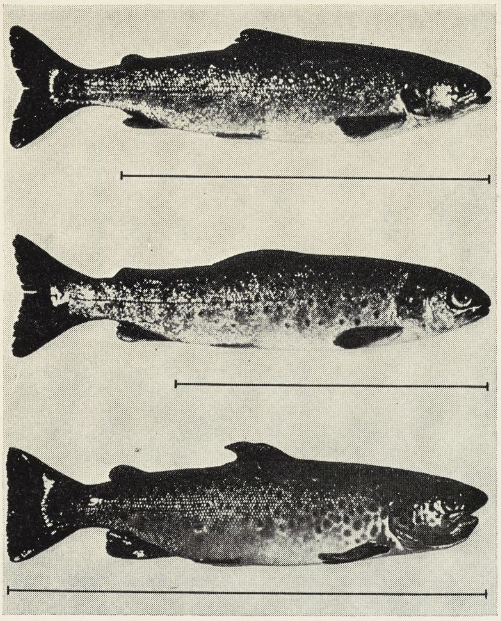

Fig. 1. Top to bottom: salmon, trout and F_1 hybrid.

Cytological studies

At the Swedish Salmon Research Laboratory, Älvkarleby, our group in 1967 made fixations of kidney tissues and testes as well as of material derived from crossings between salmon and trout (field number B 233, 65-902) obtained from Dr D. Piggins at Newport, Ireland. This material was not studied until 1971 in the autumn, and it was then found that all specimens fixed had the chromosome number 2n = 80 and thus were trouts and not hybrids between salmon and trout.

During the years after receiving the supposed hybrids from Dr. Piggins, back-crosses had been made to salmon and trout at Älvkarleby. As the supposed original hybrid was trout and not salmon×trout these "back-crosses" resulted partly in real hybrids between Irish sea trout and Swedish salmon and partly in hybrids between Irish and Swedish trout. This was confirmed by chromosome studies of specimens from the crosses in question. The only cross of real interest for our investigation involved a salmon female, 70-811 Luleå, crossed with a male from Piggins, 65-902. This cross resulted in about 3.000 specimens, all hybrids (Fig. 1). In the autumn of 1971 we fixed 24 individuals of this combination, 11 of which were males. Four out of these were treated with colchicine in the traditional way (NYGREN, NILSSON and JAHNKE 1968). Thirty-nine mitotic plates have been studied, 14 of which had chromosome numbers between 2n = 68 and 2n = 72. The chromosome number 2n = 69, which is the sum of 58/2 (haploid chromosome number of the salmon) and 80/2 (haploid chromosome number of the trout) was found in a number of plates, all counted in material from kidney tissue. This number has been confirmed in 1974 in plates from leukocytes obtained by tissue culture.

The meiotic pattern in the hybrid deviates in several respects from the mode of meiosis in the parents. In most trout populations studied in Scandinavia only bivalents have been observed (NYGREN, NILSSON and JAHNKE 1971, p. 260), while as a contrast in salmon the number of quadrivalents, hexavalents and octovalents is considerable (NYGREN, NILSSON and JAHNKE 1968, p. 50). Most of these multivalents in salmon appear as ring configurations, while no such units are found in the hybrid, in spite of the fact that the genome of the hybrid holds a haploid set of chromosomes from the salmon, in which rings of up to eight paired chromosomes have been observed. On the other hand a number of bivalent, trivalent and even quadrivalent chains have been found in the meiosis of the hybrid. Thus reciprocal translocations rather than autopolyploidy have caused the occurrence of ring multivalents in the meiosis of the salmon.

According to the diagram in Fig. 2, during October 1973 crossings were made between a female salmon from Luleå (12) and two male hybrids (93 and 94). In Fig. 2 these combinations are indicated by 74-900 and 74-901. At the same time a control cross was made between the Luleå female salmon 12 and a male salmon 11 (74-95 in Fig. 2). Simultaneously a female trout 1 from Luleå was crossed with the hybrid males 93 and 94 (74-902 and 74-903 in Fig. 2). As a control a female and a male trout 1 from Luleå were crossed (74-904).

Observations of the crosses were first made in March and April 1974. Already at this time it was obvious that the individuals in the controls were normal, while those of the crossings with the hybrid males were severely disturbed. Thus the

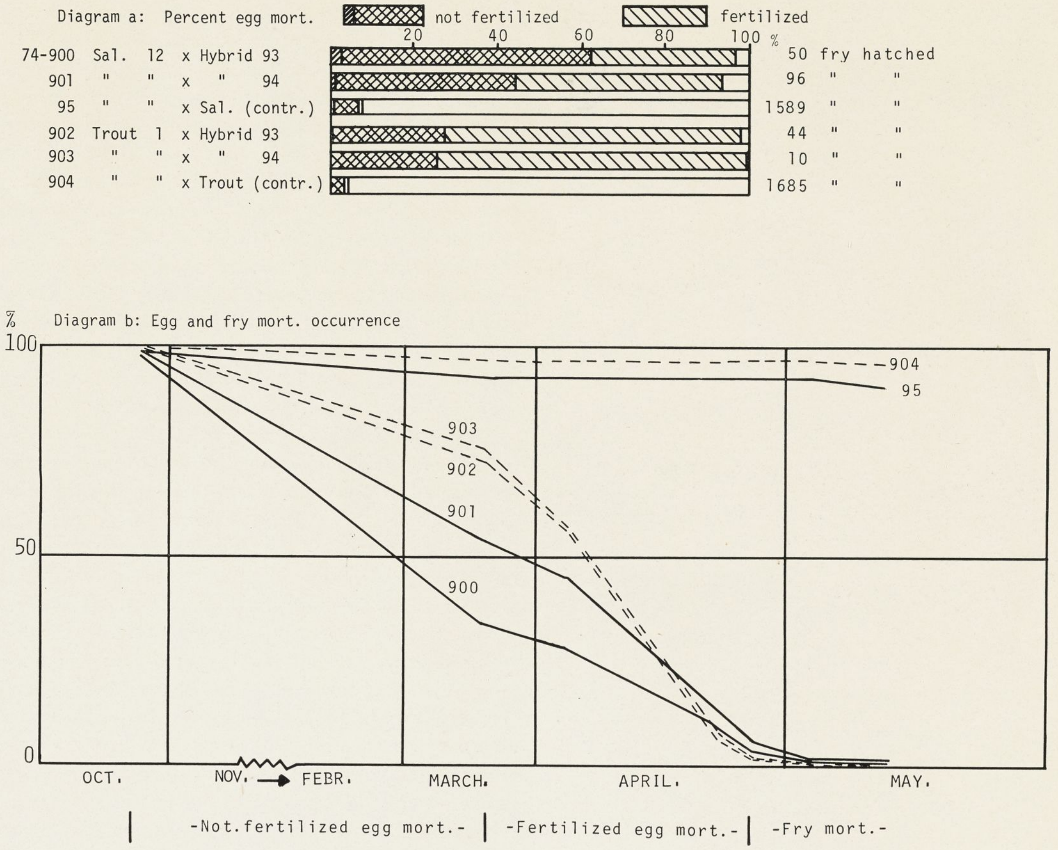

Fig. 2. Diagram of the survival of fries from crosses between salmon and trout and back-crosses to salmon-trout hybrids.

eye points in these specimens were closer to each other than in those of the controls. Further the hatching proceeded very slowly in the back-cross combinations. Some of the hatched individuals hatched with their heads first, others only hatched partially and later on died.

Attacks by fungi were common during the hatching in the back-cross combinations. In the middle of August 1974 six individuals only were left in the combinations 900 and 901 (salmon× hybrid), while all individuals in the crosses between trout and hybrid (902 and 903) had died. At the same time 1589 individuals were left in the salmon×salmon control (74-95) and 1685 in the trout×trout control (74-904). In the middle of September 1974 four individuals only were left of the combinations 900 and 901 (Fig. 3), and therefore we decided to study these specimens before they died The four individuals from the combinations 900 and 901 varied considerably in size. Their lengths amounted to 93, 72, 62 and 48 mm while the normal length of an eleven month old salmon is around six to seven centimeters. It is common for trout offspring to be very variable in size.

All four individuals were fixed for cytological studies in Carnoy (3 parts ethanol and 1 part acetic acid) without colchicine treatment and were at the same time prepared for electrophoretical studies.

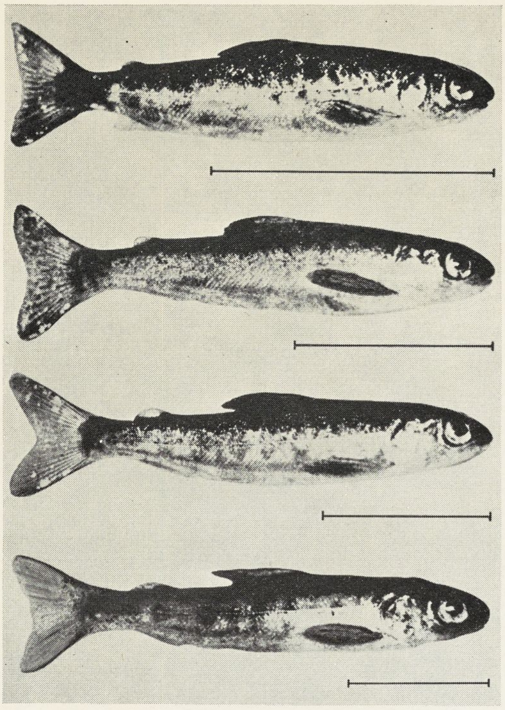

Fig. 3. The four salmon× hybrid individuals left by the middle of September 1974. Their length was at that time 93, 72, 62 and 48 mm.

Chromosome counts could be made on the largest (93 mm) and the smallest (48 mm) individuals only. Five determinations of the largest specimen gave the chromosome numbers 2n = 60, 60, 66, 66, and 66, while one determination of the smallest one showed 2n = 64 (Fig. 4). It was possible to work out karyograms of four plates of the largest specimen, two of which are given in Fig. 5 and 6. In Fig. 5 we can count 22 metacentric and 44 acrocentric chromosomes, which gives a N.F. value of 88, while 91 has been found in the salmon×trout hybrid, 100 in the trout parent and 116 in the salmon.

Biochemical studies

The esterases in muscle, serum and liver and the total protein (Amido black) of serum and muscle were analyzed electrophoretically. Samples were obtained from Atlantic salmon, sea trout, F_1 hybrids and four individuals emanating from a back-cross (F_1× salmon). Sampling procedure, electrophoretic technique and staining methods were described previously (NYMAN 1970).

In the beginning of this paper some references were given to earlier examples of artificial hybridization between salmon and trout. The simple combination of parental patterns in the F_1 hybrid as evidenced by NYMAN (1965, 1967) provided the basis for an investigation into natural hybridization (PAYNE et al. 1972). These authors examined 4431 sea-run fish classified morphologically as salmon, and electrophoretic analyses showed that 17 were hybrids with trout.

The level of introgression in these samples (obtained off the British Isles) varied from 0.15 to 1%, which shows that hybridization between these two species is very rare. No F_2 or back-cross individuals were detected, which is hardly surprising since the probability of a natural mating between two F_1 hybrids would be less than 0.000005 (PAVNE et al. 1972). These authors also discussed the presumed genetic instability of back-cross individuals and biological implications of salmon/trout hybridization. In the present investigation the simplicity of identifying F_1 hybrids is realized once more (Fig. 7). Except for the liver esterase pattern all protein patterns examined display in the hybrid a direct combination of the parental patterns. As could be expected there is much more variability in the back-cross individuals (Fig. 7). In the most anodal part of the muscle esterase pattern (Fig. 7,1), two individuals display patterns indicative of F_1 hybrids, whereas the other two are indistinguishable from salmon. In the more cathodal part of the pattern all four specimens are indistinguishable from salmon. This enzyme may thus be considered of little value in a search for back-cross status. The slight differences between the two species in muscle proteins (Fig. 7,2) are also reflected in the variability of the back-cross patterns, which among them contain patterns indicative of salmon, trout and F_1 status. These proteins are thus of no use for classification.

The serum esterases of salmon and trout are monomorphic but the band of each species differs considerably in electrophoretic mobility (Fig. 7,3). The F_1 hybrid typically contains both bands, and since the back-cross was made with a salmon parent, all individuals should possess patterns

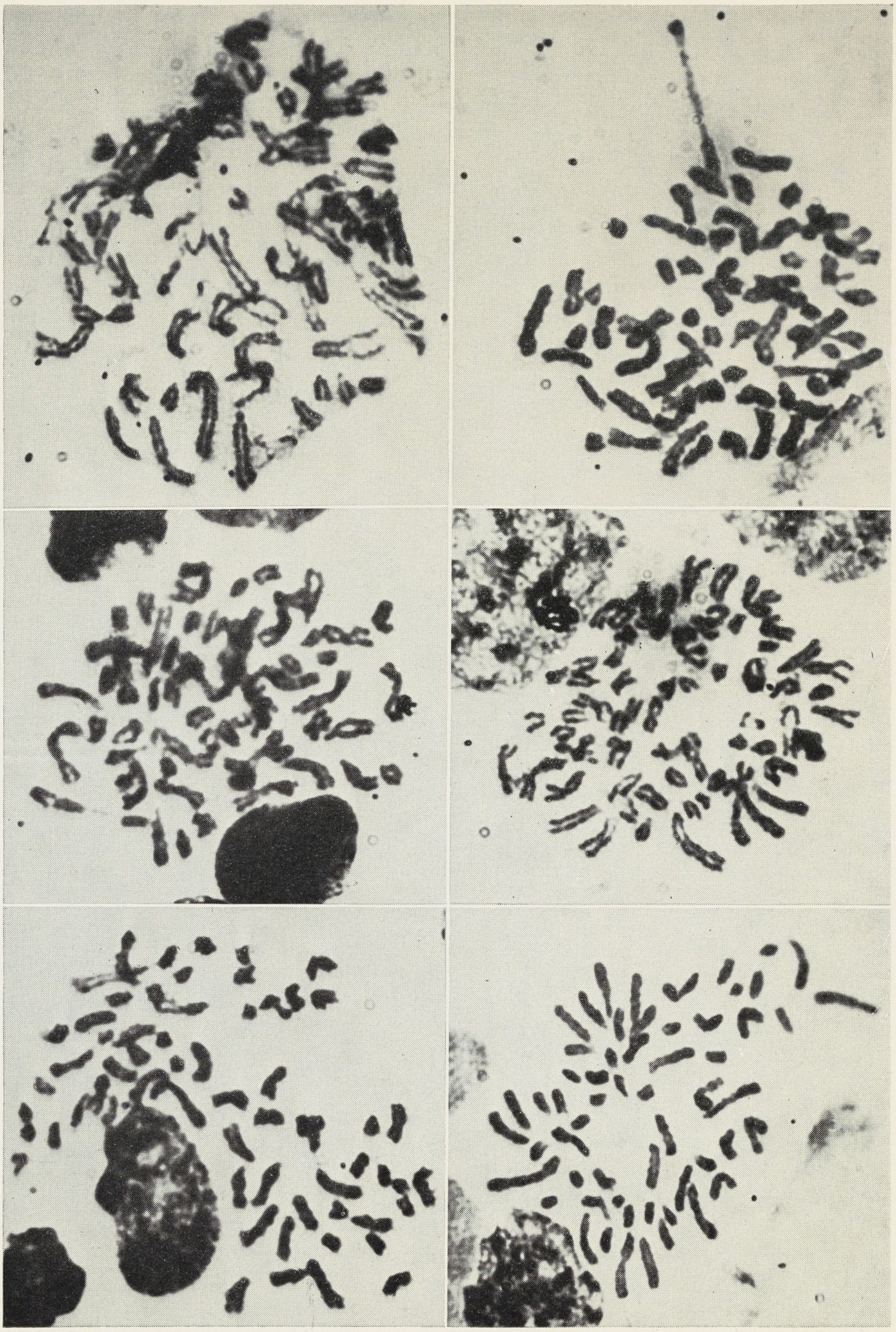

Fig. 4. Chromosome plates from salmon× (salmon× trout) individuals. Top row, 2n = 64 and 2n = 66. Middle row, 2n = 66. Bottom row, 2n = 60. ×0000000.

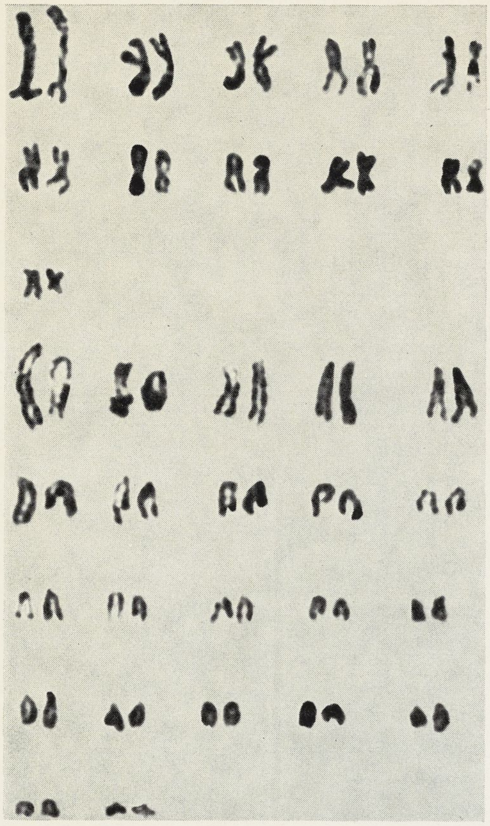

Fig. 5. Karyogram of salmon × (salmon × trout). 22 metacentric and 44 acrocentric chromosomes. N.F. value of 88. × 0000000.

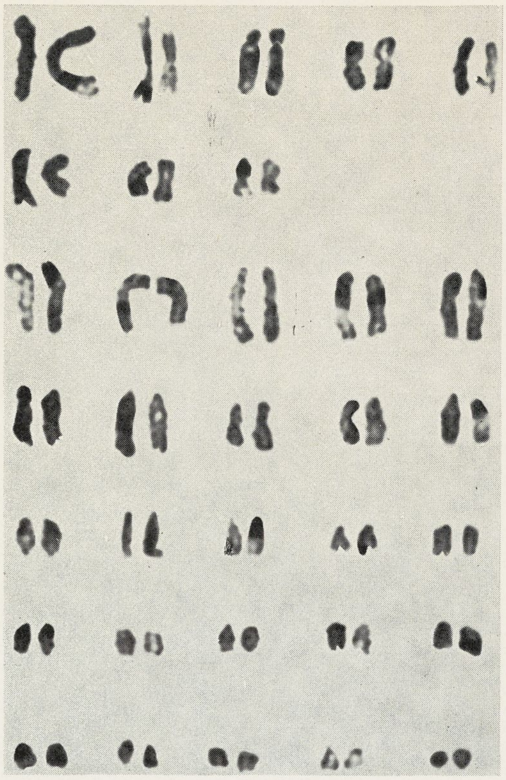

Fig. 6. Karyogram of salmon × (salmon × trout). × 00000.

either of the salmon or the F_1 type. This is also the case. Only one individual was sufficiently big for serum protein sampling, and its protein pattern was indistinguishable from that of its salmon parent (Fig. 7,4). The most cathodic of the trout liver esterase isozymes is evidently not transferred to the F_1 hybrid (NYMAN 1970), and the loss of this gene is also indicated in the back-cross patterns where similarity of either salmon or F_1 is the rule (Fig. 7,5).

Thus no single protein system appears appropriate for establishing back-cross status. If, however, the patterns of each individual are compared the following result emerges:

Back-cross	Protein pattern most similar to salmon	F_1	trout
No. 1	x	xxxx	
2	xx	xx	
3	xx	xx	
4	xx	xx	

Consequently, all fish display characters of both salmon and F_1 origin which, of course, is strong evidence of a back-cross where one of the parents is a salmon. An electrophoretic technique in-

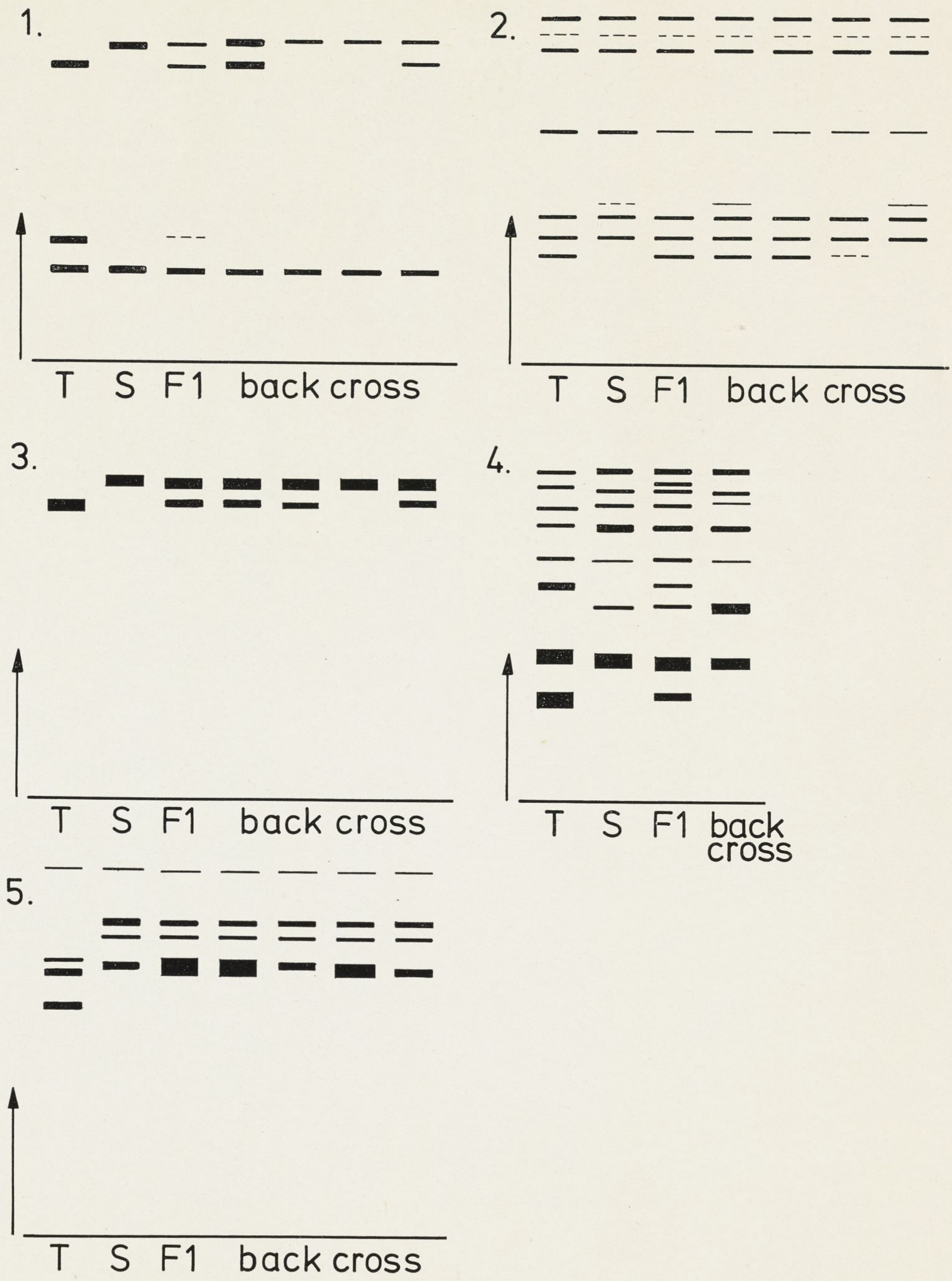

Fig. 7. Protein and enzyme patterns of salmon, trout, F 1 hybrid and back-crosses (F 1×salmon).
1. Muscle esterase
2. Muscle protein (Amido Black)
3. Blood serum esterase
4. Blood serum protein (Amido Black)
5. Liver esterase

volving several staining techniques and tissues thus may be an efficient way of evaluating backcross status of individuals derived from the combination of an F_1 hybrid of salmon and trout with a salmon.

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Effects of Thyroid Hormones on Behavior of Yearling Atlantic Salmon (*Salmo salar*)

J.-G. Godin,[1] P. A. Dill, and D. E. Drury

Department of Biology
St. Francis Xavier University, Antigonish, N.S.

Godin, J.-G., P. A. Dill, and D. E. Drury. 1974. Effects of thyroid hormones on behavior of yearling Atlantic salmon (*Salmo salar*). J. Fish. Res. Board Can. 31: 1787–1790.

Swimming activity, aggressive behavior, and upstream orientation of yearling Atlantic salmon (*Salmo salar*) treated with 6.43×10^{-11} M thyroxine were significantly lower than those of control fish injected with solvent alone. Two concentrations of triiodothyronine (7.43×10^{-11} M; 7.43×10^{-10} M) caused similar but less pronounced effects.

Because similar behavioral modifications accompany smolt migration, we hypothesize that thyroid hormones may play a role in arousing migratory tendencies in Atlantic salmon.

Godin, J.-G., P. A. Dill, and D. E. Drury. 1974. Effects of thyroid hormones on behavior of yearling Atlantic salmon (*Salmo salar*). J. Fish. Res. Board Can. 31: 1787–1790.

La nage, le comportement agressif et l'orientation à contre-courant de saumons atlantiques (*Salmo salar*) de l'année, injectés de 6.43×10^{-11} M de thyroxine, sont nettement plus faibles que ceux de témoins traités au solvant seul. Deux concentrations de triiodothyronine (7.43×10^{-11} M; 7.43×10^{-10} M) produisent des effets semblables mais moins prononcés.

Etant donné que la migration des smolts est accompagnée de modifications semblables du comportement, nous émettons l'hypothèse que les hormones thyroïdiennes peuvent jouer un rôle dans le déclenchement des tendances migratoires chez le saumon atlantique.

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In freshwater streams, Atlantic salmon (*Salmo salar*) establish and maintain bottom-feeding territories (Kalleberg 1958) by displaying aggressive behavior (Keenleyside and Yamamoto 1962; Symons 1968, 1970). At the end of their stream residency, salmon undergo smoltification and migrate to the sea. Although the cause of behavioral changes transforming an aggressive, stream-dwelling fish to a schooling, migrating one is not known, several investigators have suggested a possible role of the thyroid gland in the physiology associated with smoltification. Hoar (1939), Fontaine et al. (1952), and Leloup and Fontaine (1960) observed that the thyroid gland of the Atlantic salmon becomes hyperactive during the smoltification period. Eales (1965) showed that yearling steelhead trout (*S. gairdneri*), which do not normally smoltify, have a less pronounced spring increase in thyroid activity than 2-yr-old potential smolts. Silvering of the flanks, which characterizes the smolt, has been induced prematurely in steelhead trout (Robertson 1949), Atlantic salmon, and brown trout (*S. trutta*) (Landgrebe 1941), with injections of mammalian thyroid extracts. Baggerman (1963) demonstrated an increased salinity preference in TSH-treated juvenile Pacific salmon (*Oncorhynchus kisutch* and *O. gorbuscha*).

In the absence of data relating thyroid hormones to behavior of young Atlantic salmon, we investigated the effects of two such hormones (thyroxine and triiodothyronine) on swimming activity, aggressive behavior and rheotactic behavior, each of which undergoes a change at the time of smoltification and migration.

[1]Present address: Department of Zoology, University of British Columbia, Vancouver, B.C.

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Materials and methods — Yearling Atlantic salmon were obtained from the Antigonish Fish Culture Station, Frasers Mills, N. S. They were held in 400-liter fiberglass "living stream" tanks (Frigid Units, Inc., Toledo, Ohio) at 12 ± 1 C on a 16L:8D photoperiod and fed Purina Trout Chow twice daily (0815 and 1515). The water current was approximately 12 cm/s at the surface, and the water level was maintained at a depth of 25–28 cm.

The fish (mean length 15.4 cm) were injected intraperitoneally (without anesthesia) with either hormone or solvent as follows: L-thyroxine, sodium salt or L-3, 3′-5-triiodothyronine, sodium salt (T_3) was dissolved in a solvent consisting of 2 vol EtOH: 1 vol 0.5N NaOH and then diluted 1:20 with 0.6% NaCl. Final concentrations of 6.43×10^{-11} M L-thyroxine, 7.43×10^{-11} M, or 7.43×10^{-10} M T_3 was injected in a volume of 0.1 ml. Control fish were injected with 0.1 ml of the solvent. Additional injections were given 2, 6, and 10 days later.

On day 6, six control fish and six treated fish were transferred to separate observation tanks. The observation tanks were similar to the holding tanks except that the former had a gravel substrate and were 100 cm × 57 cm with 25–28 cm of water. The behavior of the fish was observed through a glass window on one side of the stream tanks on days 7, 8, 9, 11, 12, and 13, in the experiments with T_3 and on days 7, 8, 9, and 11, in the thyroxine experiment. The observer was obscured behind a screen of black cloth in a darkened room.

All observations were made in July and August, at which time the thyroid gland of juvenile Atlantic salmon (held under simulated summer conditions) is expected to be relatively inactive (Hoar 1939). Control fish and treated fish were observed during two daily 25-min periods each in the early morning and late afternoon, at least 40 min after feeding, because some components of aggressive behavior are enhanced immediately after feeding (Keenleyside and Yamamoto 1962).

TABLE 1. Effects of thyroid hormones on swimming activity and aggressive behavior of Atlantic salmon (*Salmo salar*). Numbers in swimming activity column refer to number of grid lines crossed by fish in tank during two daily 10-min periods. Aggressive behavior column refers to number of aggressive acts observed in two daily 15-min periods. Six fish were used per test. Thyroxine data was averaged over 4 days and T_3 data over 6 days.

Treatment	Swimming activity Mean ± SD	Aggressive behavior Mean ± SD
Thyroxine (6.43×10^{-11} M)	26.0±25.6[a]	5.5±3.4[b]
Control (solvent only)	110.0±46.0	27.8±8.9
Low T_3 (7.43×10^{-11} M)	62.2±57.6	12.7± 8.8[a]
Control (solvent only)	109.8±52.2	33.2±14.7
High T_3 (7.43×10^{-10} M)	97.2±74.3[b]	60.5±89.6
Control (solvent only)	304.8±44.5	41.8±32.4

[a] Probability of greater t value 0.05 (two-tailed).
[b] Probability of greater t value 0.01 (two-tailed).

TABLE 2. Orientation of fish with respect to water current. Direct upstream orientation is represented by 0 degrees. Values indicate total number of fish falling in each orientation class before and after two daily 25-min observation periods. Thyroxine data was summed over 4 days and T_3 data over 6 days.

Treatment	Orientation classes 0±45°	90±45°	180±45°	Probability (Chi-square)
Thyroxine (6.43×10^{-11} M)	52	28	16	≤0.05
Control (solvent only)	94	2	0	
Low T_3 (7.43×10^{-11} M)	130	14	0	>0.05
Control (solvent only)	125	13	6	
High T_3 (7.43×10^{-10} M)	67	41	36	≤0.05
Control (solvent only)	112	32	0	

The bottom of each tank was divided into 12 equal areas (0.025 m^2 each). Swimming activity was measured by cumulating the number of grid lines crossed by fish during the first 10 min of each observation period. Means were calculated for each group by averaging over the total number of observation days. During the remaining 15 min of the observation period, aggressive behavior patterns including charging, nipping, chasing, approaching, frontal display, and lateral display (Keenleyside and Yamamoto 1962; Symons 1968) were recorded verbally on tape. All aggressive acts were totalled daily for each group of fish. The mean of these over the total number of observation days gave an index of aggressive behavior.

Just prior to and after the 25-min observation periods the orientation of each fish relative to the current was recorded. The directions were classified as being upstream (0 ± 45°), perpendicular (90 ± 45°), or downstream (180 ± 45°). These were then summed for each class over the days of observation in each group.

Results — In general, there was a decrease in the swimming activity of hormone-treated fish compared with that of control fish (Table 1). This reduction is significant ($P \leq 0.05$) for thyroxine-treated fish and highly significant ($P \leq 0.01$) for fish treated with the higher concentration of T_3. Highly significant ($P \leq 0.01$) and significant ($P \leq 0.05$) reductions in aggressive behavior were demonstrated by fish treated with thyroxine and the lower concentration of T_3, respectively, compared with the controls. Fish treated with the higher concentration of T_3 demonstrated a nonsignificant increase in aggressive behavior. Upstream orientation of fish treated with thyroxine and T_3 at the higher concentration was significantly less ($P \leq 0.05$) than that of controls (Table 2); the lower concentration of T_3 had no significant effect.

Discussion — The results of this study indicate that thyroid hormones have an effect on various aspects of the behavior of yearling Atlantic salmon in an artificial stream. In all experiments, the level of swimming activity of the treated fish was reduced compared to that of the control fish. In contrast to these findings, an increase in the rate and/or amount of swimming activity has been reported in *Oncorhynchus keta* (Hoar et al. 1952), *O. kisutch*, *O. nerka*, *Carassius auratus* (Hoar et al. 1955), *Poecilia reticulata* (Sage 1968), and *Gadus morhua* (Woodhead 1970) after treatment with thyroxine. Perhaps yearling Atlantic salmon react differently to thyroid hormones. Although the possibility that some of the reported findings may be pharmacological effects cannot be conclusively ruled out, the hormone dosages we used fell within the range of physiological levels reported for brook trout by Eales (1974).

In preparation for its downstream migration, the Atlantic salmon must abandon its bottom-feeding territory. A reduction in swimming activity that would lead to a decrease in social encounters, may accomplish this. A direct reduction in aggressive behavior could also accomplish this, and in addition, would permit an increase in migratory schooling. Hoar (1951) observed just such a reduction in the aggressive behavior of territorial coho salmon (*O. kisutch*) during smoltification, and our results show that in Atlantic salmon thyroid hormones could be the cause of this reduction.

Atlantic salmon parr, in a nonmigratory stage, orient against the current in artificial streams (Kalleberg 1958) and in rivers (Keenleyside 1962). Migrating smolts swim with the water current in circular tanks (Kalleberg 1958) and in rivers (Stasko et al. 1973). Upstream orientation of our fish treated with 6.43×10^{-11} M thyroxine and 7.43×10^{-10} M T_3 was significantly reduced.

Minimal requirements for downstream migration of Atlantic salmon would appear to include a reduction in aggressive behavior, and a downstream orientation. From the present data, it is suggested that thyroid hormones may be involved in the behavioral changes associated with migration in Atlantic salmon. It remains to test how these findings in an artificial stream, relate to the migratory behavior of salmon in natural streams.

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