Agenda 5.4(a)
For decision

Council

CNL(01)21

Report of the Meeting of the Working Group on International Cooperative Research

1. Last year the Council agreed to set up a Working Group to develop ideas for a research programme to identify and explain the causes of increased marine mortality of Atlantic salmon and to examine the possibilities to counteract the mortality. The Working Group was asked to advise on possible sources of funding for the research programme and how to organize it, and to consider the issue of by-catch in pelagic fisheries.

2. The Working Group met in Oslo, Norway, during 10-12 October 2000 under the Chairmanship of Dr Lars Petter Hansen. The report of the meeting is attached. The Group's recommendations, if adopted, would have financial and administrative implications for NASCO. These will be reviewed by the Secretariat in document CNL(01)22.

Secretary
Edinburgh
1 December, 2000

ICR(00)10

Report of the Meeting of the Working Group on International Cooperative Research

Oslo, Norway, 10-12 October, 2000

1. Introduction

1.1 The Chairman, Dr Lars Petter Hansen (Norway), opened the meeting and welcomed participants to Oslo. He introduced Mr Steinar Hermansen, Deputy Director at the Royal Ministry of Environment in Oslo, who added his welcome and referred to the importance of the meeting given the general decline in Atlantic salmon stocks around the North Atlantic. He stressed the importance of a better understanding of the marine phase of salmon but referred to the considerable expense involved in research on salmon in the sea. There is, therefore, a need for international cooperation to ensure efficient use of resources and to achieve significant scientific results. He noted that the success of this NASCO initiative to increase research at sea will be highly dependent on concerted and coordinated contributions from all the Parties. He referred to the need to find an efficient way to organise and finance a cooperative research programme and his personal view was that advantage should be taken of existing organizations such as NASCO and ICES. He wished all participants a productive and successful meeting and an enjoyable stay in Oslo.

1.2 A list of participants is contained in Annex 1.

2. Appointment of Rapporteur

2.1 The Working Group appointed Dr Peter Hutchinson as Rapporteur for the meeting.

3. Adoption of the Agenda

3.1 The Working Group adopted its agenda, ICR(00)8 (Annex 2), after including a new item 5(iii) entitled "By-catch of Atlantic salmon" and after making minor changes to item 6.

4. Terms of Reference of the Working Group

4.1 The Secretary of NASCO, Dr Malcolm Windsor, referred to the desirability of NASCO being science-based in its decision-making but noted the lack of information on the marine phase of Atlantic salmon. He indicated that some years ago NASCO had been compared to a vehicle with a rear-view mirror but no windscreen since there was a lack of predictive advice on which to base management decisions. This had now changed and he thanked the scientists present who had been involved in the development of the predictive models used in agreeing regulatory measures for the West Greenland fishery. He noted the importance of the task facing the Working Group as detailed in the Terms of Reference from the Council of NASCO. These contain two elements: what research is needed to better understand the factors responsible for the increased marine mortality of salmon and how can this research be

financed? The Working Group considered its Terms of Reference, ICR(00)2 (Annex 3).

5. The International Cooperative Research Programme

(i) Background

5.1 The Chairman introduced document ICR(00)4 which provided background information on the decline in salmon abundance, a significant proportion of which has been attributed to an increase in marine mortality. Many factors are thought to influence marine mortality including environmental changes, diseases and parasites, predation, competition, availability of food, exploitation in directed fisheries and as by-catch, and freshwater influences. These factors, operating alone or in combination, may affect mortality and, if sub-lethal, life history responses such as age at maturity. He stressed the considerable expense involved in studying salmon at sea and referred to the need to optimize allocation of resources through international cooperation.

(ii) Overview of Existing or Proposed Research and Development Programmes on Salmon at Sea

5.2 Reports on ongoing research at sea were presented by Canada, England/Wales, Faroe Islands, Iceland, Ireland, Norway, Russian Federation, Scotland, Sweden and USA. Summaries of these presentations are contained in Annex 4.

5.3 In addition, a report was made available to the Working Group of a recent Workshop on research strategies into the cause of declining Atlantic salmon returns in North American rivers, ICR(00)9, sponsored by Fisheries and Oceans Canada (Science Branch). A summary of this report is also contained in Annex 4 as part of the Canadian report.

5.4 The Working Group recognised that while there have been considerable advances in our understanding of salmon at sea as a result of national research programmes, the high cost of research at sea and the level of available funding had limited the knowledge gained. For example, the Working Group was advised that only one research cruise for salmon had been undertaken in the last 10 years in the North-West Atlantic (with the exception of recent work in the Bay of Fundy). In the North-East Atlantic there had been a programme of research at sea over the last 10 years which had provided much valuable information on salmon distribution at sea but much of this work had been conducted during surveys for pelagic species rather than during research cruises devoted to salmon. The Working Group recognized that improved knowledge of salmon at sea would require adequate funding for a multi-disciplinary programme of research which could take advantage of advances in technology such as those in relation to data storage tags.

5.5 The Working Group recognized that while research on salmon at sea was expensive there may be opportunities to save costs on equipment such as data storage tags if these could be purchased in large quantities for a cooperative research programme rather than in the small numbers being purchased presently by individual researchers.

(iii) By-catch of Atlantic Salmon

5.6 The Working Group considered document ICR(00)5 which contains information on salmon by-catch reported by captains of Russian vessels fishing in the Northern Norwegian Sea (65°-73°N) pelagic fisheries in the summer of 2000. A total of between 37 and 43 salmon had been reported captured mainly in surface trawls for mackerel. By-catches of salmon in this area appear to be a feature of the early part of the fishery (June/July) and on the basis of information obtained and knowledge of the number of vessels operating, it had been estimated that the total by-catch in these pelagic fisheries was likely to lie in the range 120-160 salmon. Even if this estimate was only a tenth of the real value it was suggested in the paper that the impacts on the catches of countries contributing post-smolts to the Norwegian Sea would be undetectable although the accidental capture of large numbers of salmon from a single river system would be more worrying. The paper recommended that scientific observers be placed on 5-10 vessels to verify these initial findings and that these observations be supplemented by information from research vessels fishing at the same time and at the same depth as the commercial fleet.

5.7 The Working Group welcomed the information contained in ICR(00)5. However, concern was expressed that the information provided could seriously underestimate the scale of the problem. Norwegian research fishing in the same area using surface trawls had shown that catch rates of post-smolts could be high (up to 170 post-smolts in a two-hour trawl). The Working Group recognized that there could be considerable difficulties for observers in identifying post-smolts among the large catches of pelagic fish such as mackerel on commercial fishing vessels. Such problems had been experienced by observers trying to screen capelin catches for salmon post-smolts in the North-West Atlantic. It was agreed that parallel research fishing might be a more appropriate way to estimate by-catch. The view was expressed that if the mackerel trawls could be operated at about 10m below the surface the by-catch of salmon would be reduced. It was recognized that this measure would also greatly reduce the catch of mackerel.

5.8 The Working Group was made aware of a new design of doors for use with surface trawls which have been used for research on salmon in the Bay of Fundy, Canada. However, the Danish-based manufacturers of these trawl doors had received enquiries from a number of fishermen wishing to use the gear in exploratory fisheries for pelagic species in surface waters. The development of new gear indicates that new fisheries may be targeted in surface waters. Concern was expressed that this could lead to an increased problem of by-catch of salmon in the North Atlantic.

(iv) Objectives for the International Cooperative Research Programme

5.9 The Working Group agreed that the objective for an international cooperative research programme should be to identify and explain the causes of the increased marine mortality of salmon, including by-catch and factors operating in fresh water but which subsequently affect mortality at sea. The Group recognized that it would be desirable to develop a programme of what can realistically be achieved in the next 5 years.

(v) Proposals for the International Cooperative Research Programme

5.10 The Working Group considered the scope of issues facing scientists attempting to understand the causes of mortality of salmon at sea. After reviewing ideas and project concepts, the Working Group was able to develop a short list of concepts that would productively contribute to the overall goal of understanding the causes of marine mortality. This list is not comprehensive in that some areas of research are not included. This does not reflect negatively on those areas of research not included but rather reflects the desire to provide a manageable programme of research areas for consideration by NASCO. The Working Group used a number of approaches to satisfy itself that each of these topics had high relevance to the stated objectives of the cooperative research programme. Obviously, different programme concepts examine different aspects of the overall problems and some concepts are clearly more forward-looking than others. A total of eight programme concepts were identified. Some of these, for example 'Salmon by-catches in pelagic fisheries', specifically focus on one possible mortality factor while others are more generalized. A matrix was developed which indicates the relevance of each project to increasing understanding of the various factors which could contribute to marine mortality. This matrix is contained in Annex 5. The Working Group hopes that the following list of research areas will provide a starting point for successful studies through international collaboration.

Project 1: Scale Growth Analyses

Concept: Freshwater and post-smolt (i.e. salmon in their first year at sea) growth histories are laid down in scales of salmon and can provide valuable data to evaluate the survival and maturation of salmon stocks. Comparison of these data has also helped scientists understand survival and recruitment patterns among stocks. With a greater understanding of growth dynamics, scientists will be able to improve their environmental prediction models by delineating the boundaries between stock complexes.

Approach: Existing archives of scale data have generally been measured for routine ageing. However, these samples could be measured using image processing to extract detailed growth histories. Individual laboratories and investigators could then collaborate to analyse regional and continental growth signature trends.

Timeframe: 5 years.

Resources: A number of image processing laboratories exist that could participate in this initiative. Resources could also be used initially to organize workshops and facilitate the collaboration of the principal investigators with investigators at image processing facilities (£7,000 per annum). It would be desirable to have additional resources to provide image processing systems to key laboratories and pay for temporary technical staff to carry out sample preparations and data extraction (£70,000 per annum).

Project 2: Post-Smolt and Adult Migration and Distribution

Concept: A clear understanding of the temporal and spatial dynamics of migration pathways, distribution, and habitat utilization is essential to understanding marine

mortality issues. For most Atlantic salmon stocks, marine distributions are poorly understood. Field-based efforts to describe distributions will generate significant opportunities for investigating other factors including: short-term growth rates; mortality estimates; diet composition; parasite and disease sampling; assessment of physiological condition; potential opportunities to sample piscivorous predators.

Approach: Full implementation of a coordinated research programme will require smolt tagging, research cruises, and fisheries monitoring. To understand migration pathways, it will be necessary to identify the source of post-smolts and adults intercepted at sea. A coordinated tagging programme using conventional tags and ultrasonic transmitters can be used for identification purposes. Large-scale conventional tagging programmes would be established to mark wild and hatchery smolts from representative river systems. By giving the trawling/tagging programme an appropriate design, mortality estimates at desired stages in the early oceanic phase would be obtained. Targeted use of ultrasonic tags will be an equally effective tool to determine distribution and migrations patterns of post-smolts at sea during the first year and can be used to assist the direction of trawling and fishing effort. Trawling programmes and acoustic monitoring will be used to identify post-smolt habitat and collect individuals to study marine ecology of the post-smolts.

There will be a need for enhancement of existing monitoring programmes and establishment of new monitoring programmes for remaining commercial and recreational fisheries for Atlantic salmon. The research fishing programme will be established so as to also target larger Atlantic salmon after one year at sea.

Timeframe: 5 years.

Resources: Some resources and infrastructure are already available through existing post-smolt trawling and ultrasonic tracking/monitoring programmes. In addition, some established conventional tagging programmes could be redirected in a coordinated manner to address programme objectives. New resources for conventional marking, ultrasonic tracking, post-smolt trawling, enhanced fisheries monitoring, and research fishing programmes are estimated to range from £1.5 million annually for a minimally funded initiative to £3.5 million annually for a fully funded initiative.

Project 3: Thermal Ecology of Salmon at Sea

Concept: Many studies have shown strong links between survival and growth of salmon and sea water temperature. Thus it will be essential to fully describe the thermal habitats of salmon at sea using data storage tags. An additional benefit of these studies will be to provide information on the distribution of salmon at sea.

Approach: Data storage tags will be applied to smolts and adults within the framework of an established recovery programme. Study sites will be representative of the full range of salmon in North America and Europe. Expected results include: comparison of thermal regimes among both individual fish and stocks; comparison of temperatures from data storage tags to available oceanographic climate data sets and other climate datasets; better understanding of factors affecting salmon distribution at sea.

Timeframe: 3 years.

Resources: There are a number of recovery programmes that the data storage tag programme will be based on. Minimum resources required for the data storage tag programme are £125,000 per annum. A full programme including more sites and parameters recorded on the tag would be highly desirable and would require an expenditure of £500,000 per annum. If resources are available then geolocation parameters should be collected on the tag; however geolocation information is extremely expensive to collect.

Project 4: Bioenergetic Modelling of Salmon

Concept: Bioenergetic modelling is essential for understanding growth and survival at sea and is essential for the interpretation of field data. Mortality is growth-dependent as both the effects of predators and parasites vary with the size of the fish. Furthermore the ability to survive critical periods depends on the amount of surplus energy stored by the fish.

Approach: Bioenergetics models show how fish use energy for various purposes. Through modelling we will investigate how much energy is available to fish and how it is used for growth, movement and maintenance. To make such a model internationally acceptable, it needs to be based on published data on the relationship in salmon between food consumption and growth from all marine areas of salmon. It will also use data available from aquaculture research. A preliminary model can be developed in one year. The model will be checked and developed by using datasets on growth, diet and temperature. The model will be used as a tool in projects dealing with growth, diet and mortality.

Timeframe: The entire project, including a validation process, will last 3-4 years.

Resources: The cost for this project is in the order of £80,000 a year. These costs include the costs of one full-time PhD student and the cost of a workshop to develop the input data for the model. The minimum costing based on a part-time PhD student would be £30,000 per annum.

Project 5: Trends in Marine Survival

Concept: The international research community has access to a large volume of archival data from fisheries in home-waters and in the ocean, and from the rivers and streams that receive spawning adults and produce juveniles. Matching environmental data are available both for fresh water and the ocean. Many of the data sets are accessed for national research programmes in order to monitor freshwater production, and to estimate marine abundance and survival. However, value will be increased by using new, advanced analytical methods and combining across national scales.

Approach: ICES performs some of this work routinely each year. However, additional scope for new approaches should be assessed. In particular, patterns of coherence in marine performance and survival, and the comparison of marine survival rates with variations in environmental conditions, such as sea surface temperature, will pinpoint candidate areas of concern. It will also help understanding of the mechanisms of stock regulation. New sources of archived information should be

identified, accessed and integrated into the new analyses. Since the approach is a broad one it is expected to contribute insights in many specialist areas. Additionally, the identification and characterisation of local, national, regional and Atlantic-wide trends will provide further support for the array of predictions that are required for national and international management. The objectives can be achieved at relatively low cost by building on existing collaborative arrangements and forming new ones.

Timeframe: 3 years.

Resources: Existing resources are assumed to be committed. Additional resources of £40,000 per annum are required for travel support and workshops to explore these new areas and devise new working methods.

Project 6: **Salmon By-catches in Pelagic Fisheries**

Concept: Identify interception fisheries in the North Atlantic which have the potential to have a by-catch of salmon, estimate the amount of salmon caught in these fisheries and evaluate possible management measures to minimise such by-catch.

Approach: Based on available data on the distribution, mode of operation and effort in pelagic fisheries, and on the migratory routes of salmon in the ocean, a temporal and spatial matrix describing potential overlap between salmon stocks and pelagic fisheries will be built. Based on this matrix the fisheries will be given a classification as to their impacts on salmon stocks according to their mode of operation and degree of overlap. Observers will be placed on board fishing vessels to inspect catches in order to obtain estimates of the by-catch of salmon. According to need, scientific surveys will be conducted to verify or collect additional data in addition to the data acquired by the observers. Field studies will be carried out in parallel with these surveys to devise fishing strategies yielding less by-catch in the respective fisheries. Based on the results obtained, possible management measures which could reduce by-catch of salmon will be evaluated.

Timeframe: 3 years.

Resources: Minimum - extraction of existing data and construction of overlap matrix: £35,000 per annum. Desirable - as minimum plus observers and experimental fisheries: £200,000 per annum.

Project 7: Survival Dynamics at the Freshwater Marine Transition

Concept: The objective is to estimate mortality of salmon during the transition from fresh water to the marine environment. The mortality may be caused by predation, diseases and parasites. In addition, a number of studies have indicated that conditions in fresh water, e.g. temperature and contaminants, may compromise the ability of smolts to adapt and survive in the marine environment. The magnitude of this mortality may vary considerably on a spatial and temporal basis.

Approach: A number of smolts will be tagged in rivers. Mark-recapture population estimates will be conducted for predatory animals in conjunction with stomach content analysis. This could facilitate determination of the magnitude of predation and the possible impact on adult returns. Acoustic tags could be applied to smolts

which would be actively tracked in estuaries and near shore areas to determine the length of time post-smolts spend in these areas. Physiological studies will be carried out on emigrating smolts in order to assess their ability to adapt to, and survive in, the marine environment in relation to conditions previously experienced in fresh water. Floating trawls could be used to catch post-smolt salmon in different parts of estuaries and nearshore areas to study migration, nutrition, growth and parasite burdens.

Timeframe: 5 years.

Resources: The cost of such a programme, which will involve cooperation between laboratories within the full range of the salmon, will be £100,000 per annum for a pilot project. For implementation of these projects in index areas throughout the range the cost would be £500,000 per annum.

Project 8: Application of Electronic Tag Technology to Determine Marine Distribution of Salmon

Concept: Management of salmonid fisheries is currently based upon a very limited understanding of the marine distribution of Atlantic salmon. Information is required on the spatial and temporal distribution of salmon in the sea in order to develop models to describe the movements of salmon in relation to marine currents and sea surface temperature in order to predict the impact of oceanographic and climatic conditions on marine survival.

Approach: It is proposed to further develop data storage tag technology in order to describe the distribution of salmon in the marine environment. The new generation of data storage tags incorporates a light sensor which collects data that may be used to estimate the position of the salmon in the sea (latitude and longitude) with a degree of precision. The recent miniaturisation of these geopositioning data storage tags now permits their use on fish the size of post-smolts.

Methods will be developed which will form the basis of a large-scale data storage tag study on the environmental distribution of salmon in the sea. These methods will include testing the suitability and resolution of position-fixing data storage tags, identifying appropriate stocks of salmon to maximise the return rate of tags through fishery-dependent methods and assessing the most suitable techniques for attaching tags to post-smolt salmon. The geopositioning data storage tags will also collect data on water temperature and depth of fish and provide further information on the behaviour of salmon in the marine environment. The project will also complement the other proposed programmes investigating the distribution of post-smolts and the thermal preferences of salmon in the sea.

Timeframe: 5 years.

Resources: The major cost of the project would be the purchase of the data storage tags. The number of tags required for the study would be dependent on the release site of the post-smolts and the number of tags that would be returned either through the fishery or by other means. An initial study would require the release of about 200 fish and the cost of such a tagging programme would be in the region of £300,000 per annum. It would be desirable to increase the number of study stocks, which may reduce the individual tag costs, and the use of other technologies that would increase

returns would also reduce costs. The cost of this expanded programme might be in the region of £1 million per annum. International collaboration would be necessary in order to spread the cost of the project and to identify the most appropriate river systems to study. However, the core data produced by the project would be highly relevant to all Parties and collaborating countries. In addition the successful outcome of such a study will further promote the development of fisheries-independent data storage tag technology.

Conclusions

5.11 In summary, the minimum and desirable costs (in pounds sterling) for the eight programme concepts outlined above are as follows:

Project title	**Minimum budget**	**Desirable budget**
1: Scale growth analyses	£7,000	£70,000
2: Post-smolt and adult migration and distribution	£1.5 million	£3.5 million
3: Thermal ecology of salmon at sea	£125,000	£500,000
4: Bioenergetic modelling of salmon	£30,000	£80,000
5: Trends in marine survival	Existing resources	£40,000
6: Salmon by-catches in pelagic fisheries	£35,000	£200,000
7: Survival dynamics at the freshwater marine transition	£100,000	£500,000
8: Application of electronic tag technology to determine marine distribution of salmon	£300,000	£1 million

There is, however, a strong interactive effect between the various projects so the costs will not be additive.

5.12 The complexity of the task of trying to reveal the processes underlying the general decrease in Atlantic salmon stocks throughout its range is large and should not be underestimated. Increased efforts in salmon research dedicated to this problem during the last years have led to some insight, but we are still far from a thorough understanding of the basic nature of the decline and the causal factors. At the end of the day one single factor could turn out to be critical but, more probably, a set of interacting factors will emerge as significant.

5.13 The future success of this programme will critically depend on asking the right questions throughout the programme period and on a flexible organisation model capable of extraction and utilization of all results individually and combined. The potential synergistic effects in efficient and open communication between the projects is large, and processes promoting such communication are essential to the overall programme's success. A thorough and ongoing effort throughout the programme should, therefore, be put into developing the interactivity and communication between the projects. With the limited time available to the Working Group, the interactivity between the projects could not be discussed in any depth, and time should be dedicated to this aspect as soon as possible after commencement of the programme. Assembling the information outlined in this programme would be a prerequisite to assessing whether there are measures that can be taken to counteract the mortality of salmon at sea.

6. Proposed Organization and Funding of the Programme

(i) Existing Research and Development Funding on Salmon at Sea

6.1 The Group initially discussed the definition of research at sea for the purpose of assessing existing funding and agreed that it would exclude work on all freshwater aspects of the salmon's life cycle but would include scientific programmes in estuaries. Work relating to aquaculture escapees and sea lice would be included provided it related directly to assessing salmon mortality at sea.

Country	Average annual expenditure (pounds sterling) on marine research for the period 1998-2000
Canada	£150,000
Denmark	Information not available
Faroes	£25,000
Finland	Information not available
France	Information not available
Germany	Information not available
Greenland	Information not available
Holland	Information not available
Iceland	£50,000
Ireland	£60,000
Norway	£415,000
Russia	£ 0
St Pierre and Miquelon	Information not available
Spain	Information not available
Sweden	Information not available
UK	Information not available
US	£200,000

6.2 Average annual expenditure in the period 1998-2000 by North Atlantic countries on research on salmon at sea ranges from zero to in excess £400,000 per annum. However, information was not available to the Working Group for all countries in the NASCO Convention area and the Group recommends that NASCO Parties be requested to make information on current expenditure available to the Organization. It is anticipated that total existing expenditure on salmon at sea is less than £1 million annually. This level of expenditure is only a fraction of what will be required for a clearer understanding of the factors affecting salmon at sea.

(ii) New Sources of Funds for an International Programme

6.3 The Group discussed in detail possible sources of funds to support an international marine-based research programme. It envisaged that an initial contribution to the fund might be made by each NASCO Party, so as to encourage others to contribute to the initiative and to ensure the availability of resources during the fund's first year of operation.

6.4 Possible new sources of funding would include:

NASCO Non-Government Organizations
Non-NASCO Non-Government Organizations
Corporate sponsorship
Industry sources (aquaculture, oil, brewing, distilling)
Funding initiatives (Salmon Lottery, tickets, draws, etc.)
EU Research Funds
Other International Agencies
Private Donations and Wills

6.5 The Working Group recognized that it may be attractive to potential funding organizations or individuals if contributions to the fund could be made tax free. This aspect should be given further consideration if the Council decides to proceed with the establishment of a fund.

(iii) Funding and Organization of the Programme

Introduction

6.6 The Working Group considered that there are many possible scenarios. At one extreme there would be no new money at all; the effort would be simply directed towards using existing resources more effectively and possibly diverting more effort towards the marine issue. In that case it is unlikely that much new information could be achieved. At the other extreme national resources, together with new funds, could be put into one internationally administered programme, perhaps similarly to the way that NATO exercises operate where control is given to one international organization over these resources. The Working Group felt that, though it would be helpful, the first scenario above is not sufficient to produce the resources for the significantly greater effort needed at sea. The second scenario is probably not a politically realistic option at present. A practical option would be to set up a fund within the NASCO forum. This is outlined in Figure 1.

The "Programme" and the "Fund"

6.7 The Group considered that in the present circumstances, where only a very low effort is going into this subject, the aim should now be to generate new funding for research on salmon at sea and to better coordinate the existing and new projects. To achieve this, the Working Group envisages that there be an "International Cooperative Salmon Research Programme" which consists of the sum of the constituent projects contributed to it. A contribution might simply be notification that a certain research project relevant to the Programme would be carried out. Equally it might consist of a project that needed assistance from the "Fund". The Fund consists of contributions of money from any source. The Fund contributes to the International Programme but not all projects will seek funding assistance. Some countries will just notify the Board of their marine research projects contributing to the programme. On the other hand, there may be some countries that do not presently carry out salmon research but which could benefit from the scientific results. They and others, including NGOs, might wish just to contribute money and not any other resource.

6.8 In this way the Programme could be a flexible concept that can accept contributions in many forms and from many sources. The Parties could be invited to make an initial

cash contribution to the Fund but this would be voluntary. This initial contribution might be necessary as a catalyst to attract funding from some or all of the other sources listed in 6(ii).

Structure of the Fund

6.9 The Working Group considered that, although it is unlikely that these potential contributors would be willing to pay funds to national governments, they might be persuaded to pay into an international fund set up for this purpose. Some contributors might wish to earmark their money to certain projects and the Working Group can see no reason why this should not be possible as long as the projects are within the framework of the Programme and are acceptable to the Board. The Group also felt that it was better to try to use existing structures where possible. One possible structure that would meet these aims is to set up a Trust Fund under NASCO Financial Rule 6.1. This fund would be set up with the sole aim of funding research which might contribute to our knowledge on the causes of marine mortality of Atlantic salmon at sea and of how to counteract this mortality. The Working Group discussed whether the costs of administering the research programme should be budgeted for by NASCO or borne by the Fund. While this aspect would need further consideration by the Council the Working Group believes that the administration costs should be provided from the Fund.

The Board

6.10 If NASCO Council agrees to this idea the Working Group suggests that a Board be appointed to run the Fund and coordinate the Programme. The Board might consist of one representative from each Party, i.e. seven members from the Parties, plus three members from other contributors, one of which should be from NGOs accredited to NASCO. For simplicity the rules of procedure of the Board and the financial rules of the Fund might be based on those of NASCO. The Working Group believes that the new Board would need the administrative support of the NASCO Secretariat.

6.11 Research proposals could be submitted by any Party, country, group of Parties, organization, individual or any grouping of these. Each project proposal should indicate what resources in terms of staff, vessels, and equipment they would be willing to contribute to the Programme, and how much, if anything, they would seek to use from the Fund. Where the proposal involves a payment from the Fund, the Board would decide whether the proposal met its objectives. In coming to its decisions the Board would probably need at least two sources of advice. Firstly, it would need a scientific evaluation of the selected projects to ensure scientific balance and objectivity. Taking account of the fact that fisheries research and development programmes are national rather than EU programmes, there may be a need for special arrangements for EU member states. Secondly, the Board would need financial advice on the progress of the Fund, on opportunities for new subscriptions, on costs of various options, etc. The Working Group suggests that both of these "Sub Committees" of the Board be established by the Board itself except that the Council might wish to issue some direction as to the Scientific Committee since that already exists. The Board could receive proposals at any time but it might meet annually at the time of the NASCO meeting. It should be stressed that the Board would have no role in evaluating a project sent to it by an institution for information purposes only, i.e. a project that did not seek any contribution from the Fund. However, the Board

should decide whether or not the project is within the framework of the programme. The requirement to notify the Council already exists to some extent through the NASCO Resolution on Scientific Research Fishing and Article 15 of the Convention. It would still be very important, however, to have these projects in the Programme, so as to avoid duplication and overlap and to foster better co-ordination.

Reporting and Quality Assurance

6.12 The recipients of funds would be required to make interim and final reports to the Board. In addition the projects funded should all be published and disseminated through publication in international peer review journals and communicated to ICES so that it can be used in formulating the advice to NASCO. The Board would also make an annual report to NASCO and its Contracting Parties. ICES might be invited to play a role in quality assessment of the output of the programme and/or the Board may make other arrangements for an external peer review process.

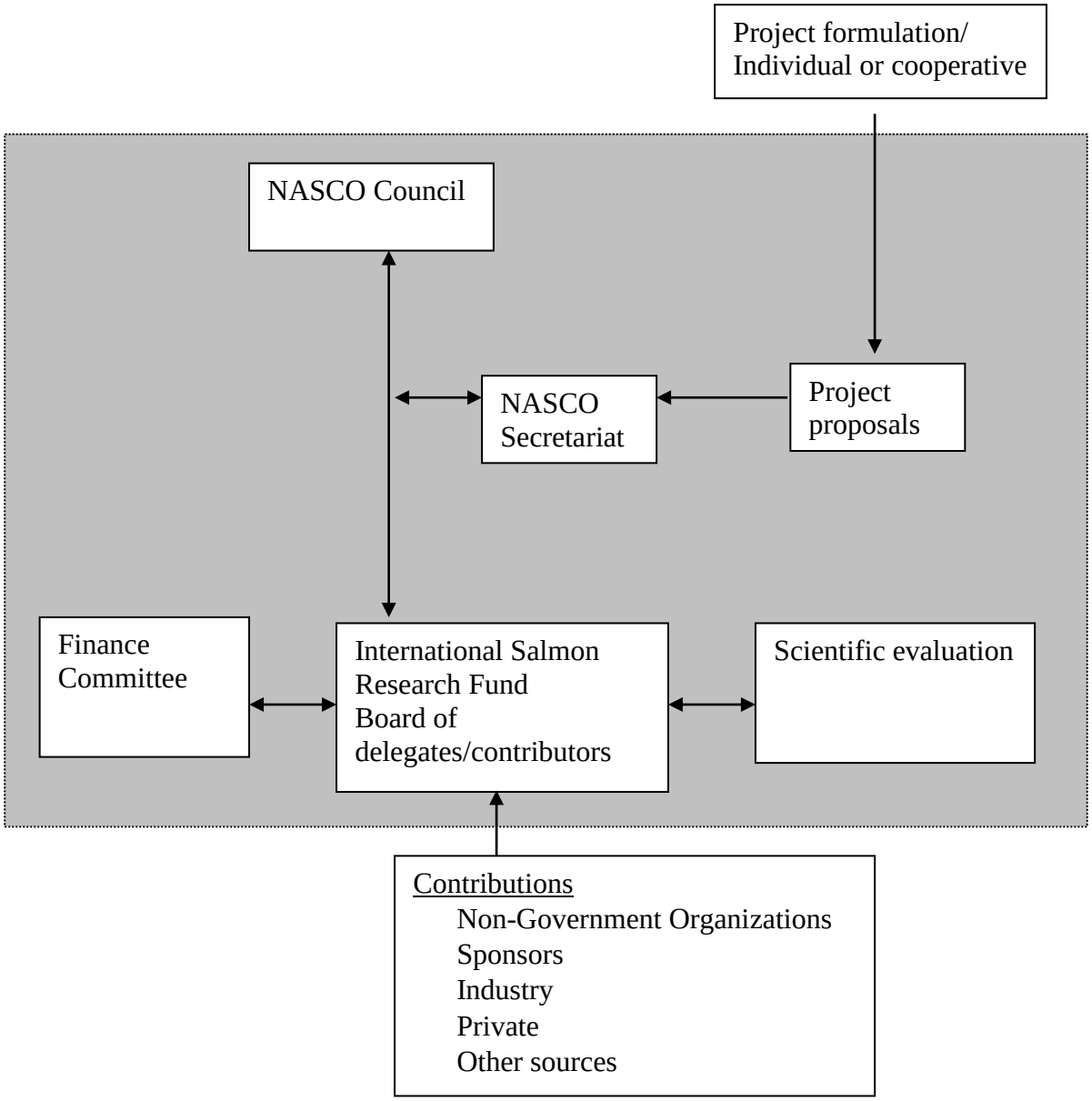

Figure 1. Possible format for the set-up of an International Salmon Research Fund within NASCO.

7. Any Other Business

7.1 There was no other business.

8. Report of the Meeting

8.1 The Working Group agreed a report of the meeting.

9. Date and Place of Next Meeting (If Needed)

9.1 The Working Group agreed that a second meeting would not be required.

ANNEX 1

List of Participants

Canada

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ANNEX 2

Working Group on International Cooperative Research

ICR(00)8

Agenda

1. Introduction

2. Appointment of Rapporteur

3. Adoption of the Agenda

4. Terms of Reference of the Working Group

5. The International Cooperative Research Programme

   (i) Background
   (ii) Overview of existing or proposed research and development programmes on salmon at sea
   (iii) By-catch of Atlantic salmon
   (iv) Objectives for the International Cooperative Research Programme
   (v) Proposals for the International Cooperative Research Programme

6. Proposed Funding of the Programme

   (i) Existing research and development funding on salmon at sea
   (ii) New sources of funds for an international programme
   (iii) Funding and organization of the programme

7. Any Other Business

8. Report of the Meeting

9. Date and Place of Next Meeting (if needed)

ANNEX 3

Working Group on International Cooperative Research

ICR(00)2

Terms of Reference

The Council of NASCO agrees to establish a Working Group, under Norwegian Chairmanship, to:

- develop ideas for a programme to identify and explain the causes of the increased marine mortality of Atlantic salmon and to examine the possibilities to counteract the mortality;

- advise on possible sources of funding for the research programme and on how to organise the programme;

- consider the issue of by-catch of Atlantic salmon in pelagic fisheries.

The Working Group should draw on existing information so as to avoid duplication of effort.

ANNEX 4

Summary Reports of Current Research Programmes on Salmon at Sea

Canada

Salar MAP: The Atlantic salmon Marine Acoustic-tagging Project

Salar MAP is a collaborative project between the Department of Fisheries and Oceans and the Atlantic Salmon Federation aimed at finding where post-smolt Atlantic salmon go at sea (fine to mesoscale migration routes and distribution over time) and capturing live salmon at sea for examination and release. The goal is to ultimately determine the location and timing of salmon mortality at sea for affected stocks and to uncover the causes. Over the past 6 years, *Salar* MAP has focused on spearheading the development of the technology and methodology to achieve these goals. New electronic tags (acoustic pingers) designed for small fish and new methods of monitoring tagged fish at sea have been used successfully to deliver information on the movement, behaviour, habitat and survival of post-smolts from the time they leave the river. Several pilot studies were conducted to highlight the possibilities.

In 1995 and 1996, both wild and hatchery-reared smolts with individually identifiable pingers were tracked for up to 3 weeks after leaving several rivers in Passamaquoddy Bay in southwestern New Brunswick. Automated pinger detection sites at key locations provided the information to determine the coastal migration routes and to assess migration success or post-smolt survival in estuaries and coastal marine habitat where salmon aquaculture cage sites are abundant. This success led to further developments (single chip pingers with multiple codes and dedicated automated receivers) to extend the tagging and tracking possibilities. Pinger length was reduced by almost half, detection range was doubled, and life span was increased up to 10 fold. In 1999, these new developments were tested in a pilot project to assess the feasibility of mapping the migration and distribution of post-smolts in the Bay of Fundy during the first summer at sea. Both wild and hatchery-reared smolts were tagged and released in a river of the inner bay. Automated receivers were strategically deployed underwater to form pinger detection screens that monitored all tagged fish leaving the river, leaving the coastal zone in a 10 km radius of the river mouth, and moving across a 50 km stretch between the inner and outer portions of the Bay of Fundy. This tracking strategy proved effective; all tagged post-smolts were detected at some time, and the movements of some of these were monitored for up to 3 months. A key feature of the approach developed is that the high efficiency of the pinger detection screens provided a measure of survival of the tagged fish to different points along the migration routes during this period. Other information obtained by tracking included the timing, location and rate of departure and return, travel direction, behaviour and movements in relation to environmental associations, and detailed tracks of individuals and group movements. The pilot project showed that automated detection screens and coded pingers could be used to track and monitor tagged fish at sea, alone or in groups, determine migration routes and distribution, examine behaviour, and determine survival over specific periods. The effectiveness of this method will depend upon location and conditions, extensive testing of pingers and receivers in the target area, and study design. For the river and stock used in the pilot study, tracking identified: a high migration success of smolts into sea water and of post-smolts away from the river mouth and coastal zone (low predation by birds), directed and active migration behaviour, high fidelity of some post-smolts to the inner Bay of Fundy during the first summer at sea, possible environmental influences on destination, and indicated that the

source of mortality common to inner bay stocks is possibly further out at sea. The new technologies and approach provided extensive fishery-independent information over ever-increasing spatial and temporal scales. These case studies highlight how ongoing novel developments in tagging and tracking fish with unique electronic devices can provide a wealth of new knowledge about specific salmon stocks and life stages in habitats where research has until now been restricted.

In 2000, *Salar* MAP focused on testing trawling gear and methods similar to that used by groups in the eastern North Atlantic to capture live salmon at sea for examination and release. A new trawl designed to maximize efficiency and fish a shallow depth (about 10 m) and several designs of towed aquariums for capturing and holding live fish were tested in a survey aboard the CCGS Alfred Needler. Surface trawling with this gear was conducted at 85 sites in the Bay of Fundy during the second half of June. The gear was successful in capturing and retaining a variety of fish alive. Three post-smolts (2 wild, 1 aquaculture escapee) and one adult salmon (aquaculture escapee) were captured. The low salmon capture indicates that some prior knowledge of migration routes and timing obtained through tagging would be of value in finding wild post-smolts because of their extremely low abundance in the Bay of Fundy. A second surface trawling survey was under way in October to try and find some older post-smolts that may have established a feeding habitat within the Bay of Fundy (a possible unique feature of this stock). Live post-smolt capture is an extension of the tracking work and a core component of the project to investigate marine mortality of salmon.

Salar MAP has focused its efforts in the Bay of Fundy because of the urgency of the situation based on the status of its salmon stocks (under consideration for listing as "endangered"). The bay provided an ecosystem that was of manageable size for developing and testing the use of acoustic telemetry to obtain both fine and mesoscale information on salmon at sea, and a similar approach could be used effectively elsewhere.

Ecology of Atlantic Salmon in the Northwest Atlantic

Exploratory fishing in the Northwest Atlantic was begun by the Department of Fisheries and Oceans Canada in 1965. Surface gillnets of various mesh sizes were set out at dawn and fished for up to twelve hours depending on the weather and wave conditions. Nets were sometimes patrolled from a small open boat to obtain live salmon for tagging. Mortalities were sampled for biological characteristics, scales, and stomach contents. Salmon of all sea ages occurred seasonally over most of the Northwest Atlantic and were found concentrated in the Labrador Sea gyre throughout the year, at west Greenland in summer and autumn, and in the spring along the eastern slope of the Grand Banks. Distribution extended as far east as the Irminger Sea. Post-smolt salmon were first caught at sea in 1987 using gillnets of small mesh sizes not previously fished. The highest concentration of post-smolts and adult salmon occurred in the mid-Labrador Sea area. Information collected from scale reading, salmon caught with tags attached, and distribution of recaptures of salmon tagged at sea indicated that salmon over the entire range in North America were found. Diet of salmon examined from stomach contents suggested that salmon were opportunistic feeders.

Experiments with data storage tags (DSTs) were conducted on Atlantic salmon kelts obtained at enumeration facilities on Western Arm Brook, Campbellton and Highlands rivers, Newfoundland in 1998. In total, data on temperature is available from 11 returned tags. Control DSTs for verification purposes were applied to kelts held in a freshwater fluvarium and indicated that water temperatures recorded by the DSTs were accurate. Results from 11 recaptured tags indicated differences between rivers and among fish within a river. Water

temperature profiles are useful for indicating water temperatures encountered by salmon in fresh water and in the sea and may prove useful for determining temperature preferences. This information is important for marine climate change models and water temperature protocols for opening/closing angling fisheries in fresh water due to high water temperatures. Movements vertically in the water column were inferred from the daily temperature patterns and indicated some diurnal movements. The Kiwi tagged salmon spent most of their time in water from 5 to 17°C.

Department of Fisheries and Oceans (Science Branch) Workshop on Research Strategies into the cause of declining Atlantic salmon returns in North American Rivers

A Department of Fisheries and Oceans (DFO) Canada salmon science workshop held in 1998 concluded that the decline in survival at sea was coincident with fundamental changes in the ecology of the Northwest Atlantic. Subsequent efforts have failed to identify the factor(s) responsible for the broad-scale decline in North American Atlantic salmon abundance. Accordingly, a second special Workshop was convened by DFO to develop an inter-Regional research focus to determine the cause(s). This Workshop took place during June 12-14, 2000, at Dalhousie University, Halifax. The 35 participants in the Workshop were multi-disciplinary in make-up, and originated from government agencies in Canada (including British Columbia), New England and Europe, as well as universities and the Atlantic Salmon Federation. The conclusions from the Workshop are now documented in a DFO-published "Proceedings" CSAS 2000/18.

The Workshop re-affirmed that the higher mortality is occurring after the salmon leave their rivers. This abnormally high marine mortality, seemingly common to all North American Atlantic salmon spawning populations, is in many cases coupled with local factors (e.g. acid rain, habitat deterioration) in some freshwater and/or near-shore areas.

Workshop participants narrowed down the list of potential causes of low marine survival to a shortened list of the most likely causes. They concluded that there could be multiple causes for low survival, including factors in fresh water that may reduce the fitness of salmon smolts going to sea and subsequently lower marine survival. Several factors, spanning the freshwater to the high seas life phases, were recommended as targets of further research.

The Workshop's principal recommendation is for a new multi-disciplinary research initiative aimed at identifying the cause or causes of the decline in sea survival experienced by North American Atlantic salmon. This proposed initiative would build on and expand the historical time series of data developed for the freshwater areas and aggressively research the marine areas from the estuaries to the high seas. Some of the potential factors identified were reduced smolt quality (freshwater effects), adverse estuarine conditions, increased predation in the marine environment, and changes in ocean migration patterns. A number of these factors may be linked to changes in climate and/or oceanographic conditions.

Maintaining current freshwater monitoring programs and expanding them to areas or stocks not adequately covered were also deemed to be essential by the Workshop participants.

Benefits from the research include better understanding of the marine ecosystem, and for Atlantic salmon, knowledge to better forecast future changes in abundance and essential information for potential mitigation of the current decline in survival at sea. Estimates are that a DFO commitment of $3 million annually (for 5 years) would probably be sufficient to lever resources from partners to fully implement the program.

The workshop developed 15 project proposals:

Size-dependent survivorship (*survival at sea is determined by smolt size*);
Freshwater conditioning (*freshwater density-dependent determinants of smolt quality*);
Physical characteristics of fresh water (*freshwater density-independent factors modify density-dependent determinants of smolt quality*);
Temperature transitions (*changes in the hydrography of the transitional zone from freshwater to marine environment*);
Coastal migration routes and energetic costs (*migration routes and costs have changed*);
Estimation of survival rates with technology (*identification of factors affecting survival rates of emigrating smolts, returning adults and post spawning kelts in estuaries and coastal waters*);
Marine fish predation in estuaries and coastal areas (*predation by marine fish has increased*);
Seals and seabird predation (*bird and seal predation reduces survival of smolts and adults in estuaries*);
Aquaculture - interactions (*aquaculture operations and escapees interact adversely with wild salmon*);
Aquaculture - disease effects (*aquaculture fish are a vector for disease transmission to wild salmon*);
Salmon distribution - models (*models would explain migration patterns and serve to probe research directions*);
Salmon distribution - coastal field studies (*using electronic tags to determine distribution*);
Salmon distribution - high seas field studies (*using cruises and electronic tracking studies to determine distribution*);
Marine mammal predation (*marine mammal observations and biological sampling*); and
Gannets as predators (*predation by gannets and indicators of ecosystem changes*).

Details on each of the projects proposed (i.e. background information, available databases to test hypotheses, time frame for completion, resources required, and the consequence for salmon if hypothesis is correct) are provided in Appendix 3 of the Workshop report.

Faroe Islands

The Fisheries Laboratory of the Faroes has carried out research on salmon in the Faroese zone for many years. The main aims of the research programme were to study the spatial and temporal stock structure of salmon, their marine feeding habits and possible interactions of escaped farmed salmon with wild salmon in the ocean. These results may contribute to a better understanding of the general biology of salmon in the oceanic phase, which may help to develop reliable assessment models of wild salmon.

The productive frontal areas north of the Faroes Islands and in the Norwegian Sea are important feeding grounds for salmon. Salmon in this area were sampled by floating long-lines (during November-March) in three consecutive fishing periods, 1992/1993 to 1994/1995, in addition to samples from the Faroese commercial fishery since the early 1980s.

Salmon that had escaped from fish farms were found intermingled with wild salmon in the Faroese zone. The proportion of escaped fish in the fishery was low until 1988, when it increased, reaching a peak around 1990 and decreasing in recent years. It was concluded that if the farmed components in the catches were not accounted for, the catches of wild salmon would be overestimated resulting in erroneous assessments of wild salmon.

Salmon originating from the entire distribution range may occur at Faroes during part of their sea phase. Most of the tagged wild salmon were recaptured in Norway, but significant numbers of returns were observed in Scotland and Russia as well. The contributions of salmon originating from other countries around the North-east Atlantic and Canada were low. Most of the fish farm escapees originate from Norwegian fish farms. It is suggested that significant proportions of the salmon caught in the Faroes area during autumn originate from southern European countries and that fish from northern regions appear to be more abundant in the winter. Recaptures in the Faroese fishery during autumn and winter of salmon tagged as smolts in different countries support this.

The salmon fed mainly on hyperiid amphipods, euphausiids, shrimps, lanternfishes, pearlsides and barracudinas, and less on larger pelagic fish and squid. However, they tend to select larger prey and prefer fish to crustaceans, if available. Escaped farmed salmon were feeding and growing as efficiently as wild salmon in the sea, indicating that those fish that survived until capture were completely adapted to feed in the marine environment. It is still an open question whether food is a limiting factor for growth and survival of salmon after the post-smolt stage in the sea.

Sea lice (*Lepeophtheirus salmonis*) were found to infest salmon in the open ocean, however, at much lower levels than in coastal areas. Practically all fish were infested, and most lice were adult ovigerous females. The infestation level increased with sea age of the wild salmon. There is a potential for transfer of lice from escaped farmed to wild salmon in the ocean, since the escaped farmed salmon had significantly higher loads of lice than wild salmon during the first winter at sea.

At present there is no research fishing on salmon in the Faroese area.

Iceland

The key factors in management of salmon in Iceland are:

- Ban on the ocean fishery;
- Constant fishing effort;
- Limited number of rods allowed for a limited number of days.

From research on catch statistic and oceanic and climatic factors it is known that:

- Catches reflect stock (run) size (confirmed with counting data);
- Stock size fluctuates depending on environmental conditions (both at sea and in the rivers);
- Stocks in the same geographic area show similar fluctuations;
- Growth rate and return rate are correlated (scale readings);
- The sea age ratio (1SW/2SW) of many stocks has changed through time and the number of 2SW fish has been low during the last decade.

The main research emphasis has been on three index rivers in Iceland's main salmon regions. Research has also been carried out in many other rivers. The research includes:

Juvenile surveys (electro-fishing);
Smolt counting;
Adult counting (return rate);
Fishery statistics (number, size and sex of every salmon);
Spawning stock size;
Mapping of the size and the quality of nursery habitats in the salmon rivers.

Other studies of salmon at sea:

Adult salmon have been tagged with data storage tags and released at sea. Results show that salmon stay in the uppermost layers of the sea but can undertake deep dives;

Studies on smolt behaviour shortly after sea migration showed that they migrate rapidly to the ocean.

Further research planned includes:

Use of small data storage tags on smolts;
Use of data storage tags on large salmon;
Use of data storage tags with GPS positioning when they become available in a few years' time;
Further studies comparing oceanic and climatic conditions and return rate of salmon (1SW and 2SW).

Ireland

Marine-Based Salmon Research

Ireland's research into marine salmon survival centres on three main areas: an extensive smolt tagging programme, a detailed adult recovery programme and a planned cooperative programme with the National Oceanic and Atmospheric Administration (NOAA)/the University of Massachusetts.

Over 500,000 nose-tagged smolts are released annually into Irish rivers. A similar programme has been in place since the early 1980s. An extensive recovery programme of adult salmon, which involves the examination of over 50% of the national catch, is also in place. These two programmes have provided a detailed database on marine survival of salmon.

Ireland has also agreed to fund research into factors affecting the marine survival of Irish salmon stocks through an ongoing Marine Institute/NOAA co-operative programme. A description of this cooperative programme is given in document ICR(00)6 and a summary of a project to identify and quantify the oceanographic factors affecting the marine survival of Irish salmon stocks is given below. In the context of a partnership approach to marine salmon research, Ireland would be willing to re-direct a proportion of its annual tagged smolt release towards a cooperative programme with countries such as, for example, Scotland, Norway and the Faroes. The tag retrieval programme for adult salmon, the adult fish counter programme and data from the Burrishoole index system, would greatly assist with the interpretation of results from such an initiative.

Marine Institute/NOAA Cooperative Project to identify and quantify the oceanographic factors affecting the marine survival of Irish salmon stocks

Recent research has shown that the marine survival and maturation rates of certain North American and European stocks of Atlantic salmon are affected by ocean temperature and chlorophyll concentrations. An analysis of historic satellite data, particularly in relation to thermal habitat and chlorophyll, could help to explain fluctuations in Irish salmon abundance. If indeed this is the case, temperature and chlorophyll data could be used in predictive models of pre-fishery abundance. These analyses could be used in conjunction with the wider analyses of marine survival of stocks in other countries to help define the major stock complexes of the north-eastern Atlantic. This would provide an important input into the ICES and NASCO advice on quota setting for high-seas interceptory fisheries of both Irish and U.S. salmon stocks.

The identification and quantification of the oceanographic factors affecting the marine survival of Irish salmon stocks will require:

- The correlation of data on Irish salmon stock abundance over the past three decades with relevant NOAA satellite and other oceanographic data on thermal habitat and chlorophyll concentrations;
- Long-term data series on survival for the stocks of the Rivers Bush, Burrishoole and Corrib will initially be used as inputs to these analyses as well as historical catch records. Assuming that statistically significant relationships are found, models will be developed to predict marine survival for these stocks as a function of temperature and chlorophyll concentrations;
- An examination of sea level pressure fields (SLP) for the same area;
- A study of the stable isotope composition of scales to evaluate trophic position over time is also under consideration.

Norway

Norwegian Institute for Nature Research: Ongoing Research on Atlantic Salmon at Sea

Monitoring of post-smolts in fjords and coastal areas:

Post-smolt salmon are caught with floating trawls at several sections of three fjords to study migration, nutrition, growth and infection by sea lice. Furthermore, some fish are tagged with hydro-acoustic tags and released into the sea.

Monitoring sea lice infection on salmon post-smolts and adults:

Infection of sea lice on post-smolts and adult salmon is routinely monitored at a number of sampling sites along the coast.

Monitoring of escaped farmed fish in catches and stocks:

At 13 marine localities and about 50 rivers, the proportion of escapes from fish farms has been estimated for several years. In the rivers, this proportion is estimated both in anglers' catches, and in spawning stocks.

Monitoring of the abundance of salmon in a fjord in Central Norway:

Over the last four years, adult salmon have been caught in bag-nets at a station located close to the inlet of the Trondheimsfjord and tagged and released. Based on recoveries, abundance and exploitation rates in the sea and in rivers were estimated.

Additional information such as infection of sea lice, and food of dead fish, was collected.

Analysis of time series on marine survival:

Salmon smolts have been Carlin-tagged in some rivers for up to 30 years to analyse marine survival (the rivers Figgjo, Imsa, Drammenselva, Halselva). In the Imsa and Halselva, all ascending and descending fish are caught in traps, and hence all fish entering the river are checked for tags.

Analysis of time series on marine growth and sea-age at maturation:

Scale samples of salmon have been collected for several years in some rivers to estimate trends in marine growth.

Pilot experiments on the use of data storage tags on salmon:

Some salmon kelts and smolts have been tagged and released in the River Imsa as a pilot study. Three kelts and three post-smolts have so far been recovered.

Total costs in 2000 were about NOK 4,600,000 (£350,000).

Salmon in the Sea

The development of new pelagic trawl technology in 1990-91 led to consistent post-smolt captures during the Institute of Marine Research, Bergen, Norway (IMR) pelagic surveys in the Norwegian Sea.

Salmon distribution has been surveyed regularly on pelagic summer cruises since 1995 in co-operation with NINA. In addition, starting in 1998, special salmon surveys have been performed in the fjords, at the coast and in the ocean.

Additional flotation on the wings and head rope is used to keep the head rope at 0m. Temperature and salinity profiles are taken at or close to the trawl positions.

During the period 1990-2000, more than 1,600 surface hauls have been performed from late May - early September, predominantly in the Norwegian Sea basin, but also in the northern North Sea, west of the British Isles and in the South-West Barents Sea.

About 2,000 post-smolts and around 100 older salmon have been captured in Norwegian fjords, in the coastal current and in the high seas areas surveyed.

Captures indicate a near surface distribution of the post-smolts.

Distinct and partly overlapping migration paths of southern European and Norwegian salmon have been revealed and it has been shown that the distribution pattern of the post-smolts is closely related to the North Atlantic current pattern.

The distribution is obviously patchy, and varies greatly between years.

The capture of post-smolts is associated with warm and saline water (9-11°C and salinity $\geq$ 35 parts per thousand).

The smolt age at capture in the Norwegian Sea is heavily biased towards 1-2 year old smolts, while a striking absence of older smolt year-classes has been noted, indicating a predominantly "southern" origin of the post-smolts caught.

Post-smolts have been observed to be opportunistic feeders, but prefer fish larvae when present.

Microtagged and Carlin-tagged post-smolts have been recaptured in the Norwegian Sea indicating the value of such tagging also for marine investigations

Post-smolt distribution in June-July overlaps with the distribution of mackerel in the Norwegian Sea. Due to the near surface nature of the mackerel trawl-fishery in this area, it may intercept with the northward migration of the post-smolts. The results of our investigations suggest that by-catches of post-smolt salmon originating from southern Europe and Norway could be significant in this fishery.

Annual internal costs for running the salmon surveys have been NOK 2.8-3.5 million (£215,000-£270,000) in 1999-2000.

The mechanisms and the migratory routes of post-smolt and older salmon are still insufficiently understood. Such understanding is crucial for the initiation of proper management tasks directed at conserving salmon stocks. A coordinated international effort to address these problems is highly desirable due to the magnitude of the task.

The extent and consequences of sea lice infections on salmon in the early marine phase

Due to an increasing production of farmed salmonids the mean concentration of sea lice larvae has increased in Norwegian fjords and coastal waters.

Sea lice have been described as a possible stock-limiting factor for salmon and sea trout stocks. In sea trout the negative effects of sea lice infections have been relatively simple to prove due to the coastal distribution of the species and its premature return to fresh water at high sea lice infections. Due to the direct ocean migration of the salmon, mortality due to sea lice infection has been difficult to prove in this species.

Through the development of the new "Fish-Lift" live catching trawling device it has been possible to catch live post-smolts in fjords of western Norway. Results of these trawl surveys during the period 1998-2000 have shown varying, but in some cases alarmingly high, levels of sea lice infection on sea-going post-smolts of salmon (up to a mean level of 104 sea lice per fish).

An experiment illustrating the severe effect of sea lice on post-smolt salmon was carried out within this project in May-July 1999. Live wild post-smolts with a natural mean infection of 31.4 sea lice were caught in a fjord in western Norway in May and brought to the Institute of Marine Research Laboratory in Bergen. The fish were fed heavily on a mix of krill and pellets and fed heavily. 5 groups of 20 fish each were de-loused while 5 other groups also of 20 fish each were left with their natural infection of sea lice. In the de-loused groups 11% mortality was observed during a period of 40 days. In the groups with natural sea lice infection the mortality was 76% during the same period. The fish in the sea lice groups died from injury caused by the sea lice.

The 24 survivors in the groups with sea lice had a maximum number of 11 sea lice per fish. This number is in accordance with the observations made in the main feeding areas of European post-smolts in the Norwegian Sea in June-August. During a 10-year period we have never found post-smolts with more than 10 adult sea lice. The fishes caught in these areas with 10 adult sea lice have shown signs of severe difficulties, illustrated by injuries in the head region and hematocrit values down to 18. These signs are exactly the same as those observed in the experiment just prior to death of the sea lice infected fish.

The results of this project have been communicated to the Norwegian fish farmers on a regular basis. Through close communication and cooperation it is hoped that the concentrations of sea lice larvae in Norwegian coastal waters can be reduced. During the winter of 2000 the fish farmers carried out a co-ordinated effort to reduce sea lice infection in their pens. The results of the trawl investigations during the spring of 2000 are promising as the mean infections on the wild sea-going post-smolts this year were the lowest recorded so far.

The fish farmers will continue their efforts to reduce sea lice infections during the coming winter. It is our hope that we will be able to evaluate the effects of these campaigns through screening of the sea-going salmon post-smolts in the coming years. Further experiments on wild sea-going smolts will also be carried out.

The annual cost of this project is approximately NOK 2 million (£150,000).

Russian Federation

Historically Russia has never fished for salmon at sea. Therefore there was no need to conduct research on the marine phase of the life-cycle. All information pertinent to this phase of Russian salmon was gathered primarily through Norwegian or Faroese research programmes.

Presently, due to financial difficulties in Russia, marine research on salmon is not feasible. Therefore, all research is now based on maintaining and upgrading the data base which has been established in previous years. In practical terms this is done through conducting monitoring on 24 rivers. These monitoring programmes provide comprehensive data on the production potential of salmon rivers and on the biology of salmon, both juveniles and adults. On the basis of these data and long-term series of data on sea water temperature in the Barents Sea, a prediction is made of the abundance of salmon stocks in Russian rivers 2 years prior to the year of return.

Another topic on which we are currently focusing is a study of the impact of enhancement on the stocks of wild salmon. This is a 6-year project and we have already obtained quite interesting results indicating that “enhanced” technologies for smolt rearing (at a higher rate) alter the genetic structure of salmon population.

Thus, the Russian contribution to meet the objectives as set for this Group could be in providing long-term data series on salmon biology and water temperature in the Barents Sea.

Sweden

There are rather small salmon stocks on the Swedish west coast and it is only from that area that Swedish salmon enter the North Atlantic. The Swedish resources allocated to monitoring

and research on the west coast are much smaller than those allocated to the much larger Baltic stocks. Existing information from the west coast that may be of interest in the present context is, for example, the existence of a limited scale archive, mainly for reared fish, going back to the 1950s. There are also counts of adult spawners and partial counts of smolts for the same period. A recent action programme for salmon on the west coast will start to be implemented at the beginning of 2001. Elements in the action programme that may be of interest are, for instance, improved catch statistics and improved monitoring of the present status of some of the stocks. The most important step may, however, be the establishment of an index river. In this river we will have monitoring of smolt output, escapement and egg deposition and electrofishing surveys. In addition, annual tagging will be carried out.

At present it seems unlikely that any additional Swedish funding will be available for an international research programme, other than that arising through reallocation of existing national funding.

UK (England and Wales)

Migration of salmon smolts in coastal waters

Telemetry studies using acoustic transmitters, acoustic sonar buoys and dedicated coastal tracking system are currently being undertaken to describe the movements of salmon smolts in estuaries and coastal waters in relation to environmental conditions.

Salmon migration routes in the sea

Models of the migration routes of post-smolts in the sea in relation to environmental and climatic conditions are being developed. Oceanographic data collected during research programmes, (e.g. sea surface temperatures, thermal fronts, shelf edge currents, tidal currents and wind driven ocean currents), together with data from micro-tagging and tracking studies will be modelled in order to predict the most likely migration routes of selected populations of salmon from the estuary to their overwintering feeding grounds.

The impact of climate change on salmon

A literature review is being undertaken to predict the proposed changes in climate on a number of population parameters (e.g. reproduction, growth and development, smolt production, migration and distribution). The study will include detailed analyses of the results from previous studies on wild salmon to examine trends between the migratory behaviour, run-timing in smolts, marine survival and water temperature.

(UK) Scotland

In Scotland, two categories of research and assessment of the marine phase of the salmon's life-cycle have been pursued in recent years. First, the biology of post-smolts has been investigated directly for fish caught in early summer in marine research cruises using surface trawls in both near-shore and off-shore locations. Second, monitoring of key research sites and of the fisheries generally has continued to provide information on marine performance, including growth, development and survival. In both cases, long time series of data are available.

The North Esk trapping facilities, coupled with surveillance and sampling of local fisheries, are used to monitor both smolt production and adult returns (since 1966). Indices of marine survival rate, treated on a whole-catchment basis, show marked declines over the period of monitoring. Smaller, tributary sites are monitored on the adjacent Dee catchment (Girnock since 1966; Baddoch since 1988), providing separate assessments for early-running (spring) salmon on a near-population basis. Declines in marine survival of salmon belonging to early-running populations have been particularly marked in recent years. Supporting environmental data is available for both the North Esk and the Dee. Both are large rivers belonging to the eastern group of watersheds that dominates total smolt production for Scotland. Recently, however, a third trapping site was commissioned on the Shieldaig, a small catchment in western Scotland, in order to monitor and investigate declines in the fisheries of this region.

Fisheries data are used to extend assessment over the whole Scottish range. Catch data supplied by commercial and sports fishermen are available from 1952. Geographical coverage is near-total and the data resolve by month (February-November) and by location (5-10km) for all legal fisheries. Commercial catches are matched with estimates of fishing effort. However, recent closures of commercial fisheries have made it necessary to consider biasing future assessments towards analysis of sports fishery catches for which realistic estimates of effort are not available. In the first part of an analysis intended to extend to all the months of the sports fishing season, rod catches of 2SW spring salmon (February-May, 1952-1997) show high levels of coherence among rivers and among months, containing signals that reflect underlying abundance. Using plausible estimates of exploitation rate, rod catch data can be used to estimate pre-fishery abundance in home waters, as well as to forecast spawning escapement.

Further, within sea-age classes, month of capture is a proxy for intended spawning location. Earlier-running fish of both the main sea-age classes (1SW and 2SW) tend to spawn in the higher altitude parts of catchments that are more distant from the sea. Experimental evidence shows that run-timing is a genetic characteristic associated with subcatchment population structuring. This and other genetic evidence shows that population structuring is a prominent feature of all the major Scottish rivers and an important factor in management. Temporal data for the sports fisheries of single rivers can be transferred to subcatchment, geographical scales in order to examine variations in the performance of populations. In recent years, trends have diverged among the spring months, showing the greatest declines for February, and greater relative declines in February and March, than in April and May. These changes cannot be attributed to changes in smolt production or in marine exploitation: they appear to be due to population-specific variations in natural marine mortality. In future, these analyses will be extended to include fishery data for all months of the season.

USA

Current and Recent Marine-Related Atlantic Salmon Research in the United States

Investigators in the United States are actively involved in research that focuses on factors affecting the growth and survival of Atlantic salmon in the marine environment. These studies include estuary and nearshore tracking studies; post-smolt trawl surveys to identify distribution; evaluation of stock-specific growth rates in the marine environment; migration and survival dynamics; analyses of hard tissues to infer marine environmental conditions and growth dynamics; and ocean climate analysis and modeling.

Estuary and Nearshore Tracking Studies

The U.S. has been monitoring the emigration of Atlantic salmon from the Narraguagus River from 1997-1999 and will resume monitoring from 2001-2003. In past years, Atlantic salmon were tracked from 12 km above head-of-tide through Narraguagus River, Estuary and Bay, until their entry to the Gulf of Maine. An array of automated ultrasonic detection units were deployed in mid-April to evaluate the number of smolts passing river, estuary and nearshore ecological transition zones. Starting in 2001, the array will be expanded into the Gulf of Maine an additional 10 km to determine how emigrating smolts relate to the Maine Coastal Current. During the emigration of wild-reared smolts, ultrasonic pingers will be implanted in 100-110 wild Atlantic salmon smolts releasing a minimum of 2 and a maximum of 8 fish each day. In some years, 15-30 pingers are also implanted in hatchery-reared smolts. The movement of smolts will be monitored through the use of this array though the end of smolt emigration - typically early June. Data are used to measure migration rates through ecological transition zones and maximum likelihood models are used to determine survival of fish as they exit the nearshore environment.

Post-Smolt Distribution, Migration, and Survival

Beginning in 2001, the U.S. will initiate an estuary and nearshore marine post-smolt trawling program in the vicinity of Penobscot Bay. Objectives of this program are to quantify the distribution and migration pathways of Atlantic salmon smolts emigrating from the Penobscot River. The presence of 170,000 marked hatchery smolts in this system will allow for development of relationships between timing of emigration and migration pathways relative to predominate marine coastal currents.

Evaluation of Stock-Specific Growth Rates

U.S. investigators are completing a project that has monitored the stock-specific marine growth rates of three stocks of Atlantic salmon raised in commercial net pen facilities at two marine sites. The commercial Aquaculture Industry raised approximately 6,000 smolts for 2 sea winters from Dennys, East Machias and Machias Rivers. Uniquely colored visual implant elastomer tags were used to facilitate stock identification and post-smolts were sampled approximately every other month during growth-out. In addition to monitoring the stock-specific marine growth rates of these three stocks, the project will also: 1) assess the marine growth rates for individual Atlantic salmon and compare these rates among stocks and two net pen sites; 2) evaluate circuli and annuli formation and timing of deposition for Atlantic salmon raised in captivity within the marine environment; 3) assess retention rates for the VIE tags applied to these smolts; 4) investigate the empirical relationships between fish growth and scale growth for Atlantic salmon from these three stocks; 5) quantitatively assess the temporal rate of the fin degradation for Atlantic salmon raised within a marine net pen.

Development of Data Storage Tags

Research continues to focus on development of smaller and cost-effective models for data storage tags that can be applied to Atlantic salmon smolts and adults. Circuitry has been developed for a small, cost-effective tag that can be applied to Atlantic salmon smolts. Additional testing is being conducted to verify the performance and reliability of the design before large-scale marking is initiated.

Analysis of Hard Tissues to Infer Marine Environmental Conditions

U.S. investigators continue to play a leading role in the analysis of scale growth patterns. Data from retrospective scale analyses are used to examine association between growth, climate, and the survival dynamics of Atlantic salmon. In 2000, a study was initiated involving the release of approximately 170,000 hatchery smolts in the Penobscot River to evaluate intra-annual variation in nearshore marine growth patterns. Atlantic salmon smolts were batch marked using visual implant elastomer tags to identify release groups. Seven major release groups (24,000 smolts per group) were released to evaluate growth and survival dynamics among stocking locations and times. Return information and scale samples collected from returning adults in 2001 and 2002 will allow for the evaluation of nearshore growth dynamics of surviving fish.

Investigators continue to conduct research in both elemental composition and stable isotope analysis of hard tissues of Atlantic salmon. A nearly completed project has examined the relationship between magnesium concentrations in the otoliths and temperature. Indications of a temperature relationship have been identified; however, follow-on studies are needed using instrumentation with a broader spatial resolution. Studies involving stable isotope analyses have been initiated to relate post-smolt feeding and diet to growth and survival dynamics.

Ocean Climate Analysis and Modeling

Research continues on the identification and quantification of thermal habitat for North American and European stocks by incorporating different climate indicators. For example, patterns in sea level pressure fields will be examined to identify climate signals. These signals can then be used to develop linkages to freshwater habitats, and address post-smolt survival issues.

Summary of factors addressed by each project in the proposed marine research programme

	Project 1	Project 2	Project 3	Project 4	Project 5	Project 6	Project 7	Project 8
	Scale growth analyses	Post-smolt and adult migration and distribution	Thermal ecology of salmon at sea	Bioenergetic modelling of salmon	Trends in marine survival	Salmon by-catches in pelagic fisheries	Survival dynamics at the freshwater marine transition	Application of electronic tag technology to determine marine distribution of salmon
Impacts of Fisheries		**	*		**	**		*
Impacts of By-catch		***				***		*
Growth effects	***	**	**	**	**	*	**	**
Maturation effects	*	*	**	**	**		*	*
Impacts of Predation	*	*	*			*	**	*
Impacts of Parasites & Diseases		**				*	**	
Environmental influences	**	**	***	**	**	*	**	**
Impacts of Pollution		*					*	*
Climatic, population trends, etc.	**	*	*	*	***	*	*	*
Charges in recruitment	*	*	*	*	**		*	*

Notes:

This matrix was prepared by the Working Group in order to illustrate the contribution each project might make to our understanding of the role played by the various factors which could influence marine survival of salmon. It was produced by asking each member of a scientific sub-group, set up by the Working Group, to score each project with regard to its relevance in increasing understanding of the role of ten factors that could influencing marine survival. The sub-group undertook this task so as to gauge the generality or specificity of the eight projects not their relative merits. The scoring system was from 1 (not valuable) to 4 (essential). These scores were then averaged and rounded, and represented in the above matrix by asterisks. Empty cells indicate that a project is unlikely to contribute to a better understanding of the role of a particular factor in the marine mortality of salmon, while *** indicates that a project is considered essential to a better understanding. The matrix represents a snapshot of the sub-group's opinions and the Working Group advises that it is not suitable for further interpretation.