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Salmon at ***Sea***

SALSEA

An International Cooperative Research Programme on Salmon at Sea

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SALSEA – An International Cooperative Research Programme on Salmon at Sea

Introduction

Background

The Atlantic salmon's anadromous life cycle involves major migrations between natal rivers and oceanic feeding grounds. Extensive research on the freshwater phase of the life cycle has revealed much about the factors affecting juvenile production, but much less is known about the salmon's life at sea. However, monitoring in rivers around the North Atlantic over the last thirty years has confirmed that there has been a significant decline in overall marine survival, particularly for southern European and North American stocks. Major restrictions on exploitation of salmon have been introduced but, to date, the salmon stocks have not responded. Lack of understanding of the factors affecting survival of salmon at sea is the key obstacle to rational management of the Atlantic salmon and to our ability to rebuild stocks. An overview of the current state of scientific knowledge about salmon at sea is presented below.

In response to concerns about the reduction in survival of Atlantic salmon at sea, the North Atlantic Salmon Conservation Organization (NASCO) established an International Atlantic Salmon Research Board (IASRB) in 2001. The objective of this Board is to promote collaboration and cooperation on research into the causes of marine mortality of Atlantic salmon and the opportunities to counteract this mortality. The first task the Board undertook was to develop an inventory of existing research so as to facilitate improved coordination, to identify gaps and to develop priorities. This inventory indicates that NASCO's Parties already spend in the region of £4.6 million (€ 6.5 million) on research on salmon at sea annually, but substantial additional funding is required if the factors affecting salmon at sea are to be better understood. The Board has agreed that its initial research priorities are to improve understanding of the migration and distribution of salmon at sea in relation to feeding opportunities and predation. Only by better understanding where the salmon are at sea, and how they get there, will it be possible to identify the factors that are influencing them. Having agreed this research priority, the Board then commissioned the development of an international programme of cooperative research on salmon at sea. This programme is called 'Salmon at Sea' or ***SALSEA*** and was developed by scientists from all of NASCO's Contracting Parties.

Current State of Scientific Knowledge

- Increased marine mortality accounts for a significant proportion of the decline in abundance of salmon stocks in recent years;
- Factors in fresh water, such as water temperatures, pesticides, endocrine-disrupting chemicals and acidification can reduce the salmon's subsequent survival in the sea;
- Smolts and post-smolts move relatively quickly into the ocean, although this behaviour may vary among populations;
- Mortality of salmon in the sea may be high during the first few months after smolts leave fresh water;

- Analysis of scale growth patterns suggests that at least some of the mortality at sea is related to changes in the rate of the salmon's growth;
- The wide variety of food items available in the ocean suggests that the abundance of larger salmon is unlikely to be sensitive to changes in availability of any specific prey item, although this may be more important for post-smolts;
- Predation on smolts and post-smolts may be most severe in estuaries and fjords. Data on predation in the open ocean is scarce;
- There has been speculation about the capture of post-smolts in commercial fisheries for fish such as mackerel but limited data are available to assess the scale of the problem;
- Parasites and diseases may affect post-smolt survival; there is particular concern about the impacts of sea lice in areas of intensive salmon farming.

Recently, there have been major advances in marine sampling methodologies, genetic techniques of stock identification, electronic tagging systems and scale analysis. The convergence of these advances now offers the opportunity to prise open the 'Black Box' containing the secrets of the Atlantic salmon's life at sea and to shed new light on the causes of its decline.

The *SALSEA* Vision

SALSEA offers a unique opportunity to increase understanding of how Atlantic salmon use the ocean: where they go; how they use ocean currents and the ocean's food resources; and what factors influence migration and distribution at sea. Our knowledge of the marine life of the salmon is so rudimentary that a thorough investigation of migration and distribution is fundamental to future survival studies in the open ocean. This is a major cooperative task but the time is right and the technology far enough advanced to give us an excellent chance of success. ***SALSEA*** seeks to draw together intellectual and scientific resources in a concerted cooperative effort to identify the factors influencing mortality of salmon at sea and the opportunities to counteract them.

Scope of the *SALSEA* Programme

The ***SALSEA*** programme contains a comprehensive mix of freshwater, estuarine, coastal and offshore elements, ensuring a comprehensive overview of factors which may affect the marine mortality of Atlantic salmon. It is a very ambitious programme that will take many years to complete, but it encompasses all of the key areas where additional scientific knowledge is required.

Factors affecting marine mortality in the inshore zone, such as those influencing the fitness of migrating smolts, those affecting the ability of fish to move from fresh to salt water (and back) and anthropogenic factors operating within the inshore zone, can be quantified and could, if appropriately funded, provide results within a relatively short timeframe.

There is also the possibility of locating areas where losses occur and identifying the causes of loss. While some research in fresh water and the inshore zone is ongoing, and funded by national agencies and partners, there is a need to enhance coordination of this work so as to get the maximum benefit from every study, and to stimulate additional support for such studies. In contrast, initial work in the open ocean has, by its very nature, proved more qualitative. Given the generally held belief that open-ocean mortality is probably the major factor driving the decline in Atlantic salmon stocks, it is essential that we develop, as soon as possible, a clearer understanding of the migration and distribution of salmon through a major, cooperative, multi-disciplinary programme of research cruises. The success of this ambitious programme will depend on initial development work (sampling gear, genetic stock identification techniques, migration models and scale analysis techniques) and this work forms part of the ***SALSEA*** programme.

Overview of the *SALSEA* Programme

SALSEA includes a series of work packages and tasks to examine key hypotheses, and it differentiates between those tasks which can be achieved through enhanced coordination of existing ongoing research, and those involving new research for which funding is required. These are illustrated in Figure 1 and are described briefly below.

Work Package 1: Supporting Technologies

This Work Package involves the development of supporting technologies in order to:

- allow identification of the origin of salmon sampled at sea through genetic stock identification methods;
- enhance the efficiency of sampling of salmon at sea through the development of improved research gear;
- identify growth histories of salmon at sea through the development of standardised scale analysis techniques.

Work Package 2: Early Migration through the inshore zone: fresh waters, estuaries and coastal waters

The factors affecting mortality of salmon at sea include those operating in fresh water which influence the fitness of emigrating smolts during the marine phase or the salmon's ability to move from fresh to saline water (and back); and man-made factors operating in the coastal zone (e.g. aquaculture). This Work Package aims to investigate:

- the influence of biological characteristics (e.g. size) of salmon smolts on marine mortality;
- the impact of physical factors in fresh water (water flow and temperature) on marine mortality of salmon;
- the influence of freshwater contaminants on marine mortality of salmon;
- the mortality due to predation in the inshore area;
- the impacts of aquaculture on marine mortality of wild salmon.

Some of this research is currently ongoing, largely funded by national agencies or partnerships with national agencies. There is, however, a need to enhance coordination of this research and to stimulate additional financial support.

Work Package 3: Investigating the Distribution and Migration of Salmon at Sea

This Work Package involves a comprehensive, multi-disciplinary post-smolt survey throughout the salmon's North Atlantic range. Work in this area has received limited funding to date, and is a priority in the ***SALSEA*** programme. This Work Package aims to:

- develop theoretical migration models from existing data so as to facilitate well-targeted marine surveys;
- develop a detailed plan for the marine survey, including standardization of survey techniques;
- conduct the comprehensive North Atlantic-wide survey to collect information on migration patterns, distribution and possible factors affecting mortality of salmon at sea;
- collate and analyse the data so obtained.

Work Package 4: Communications

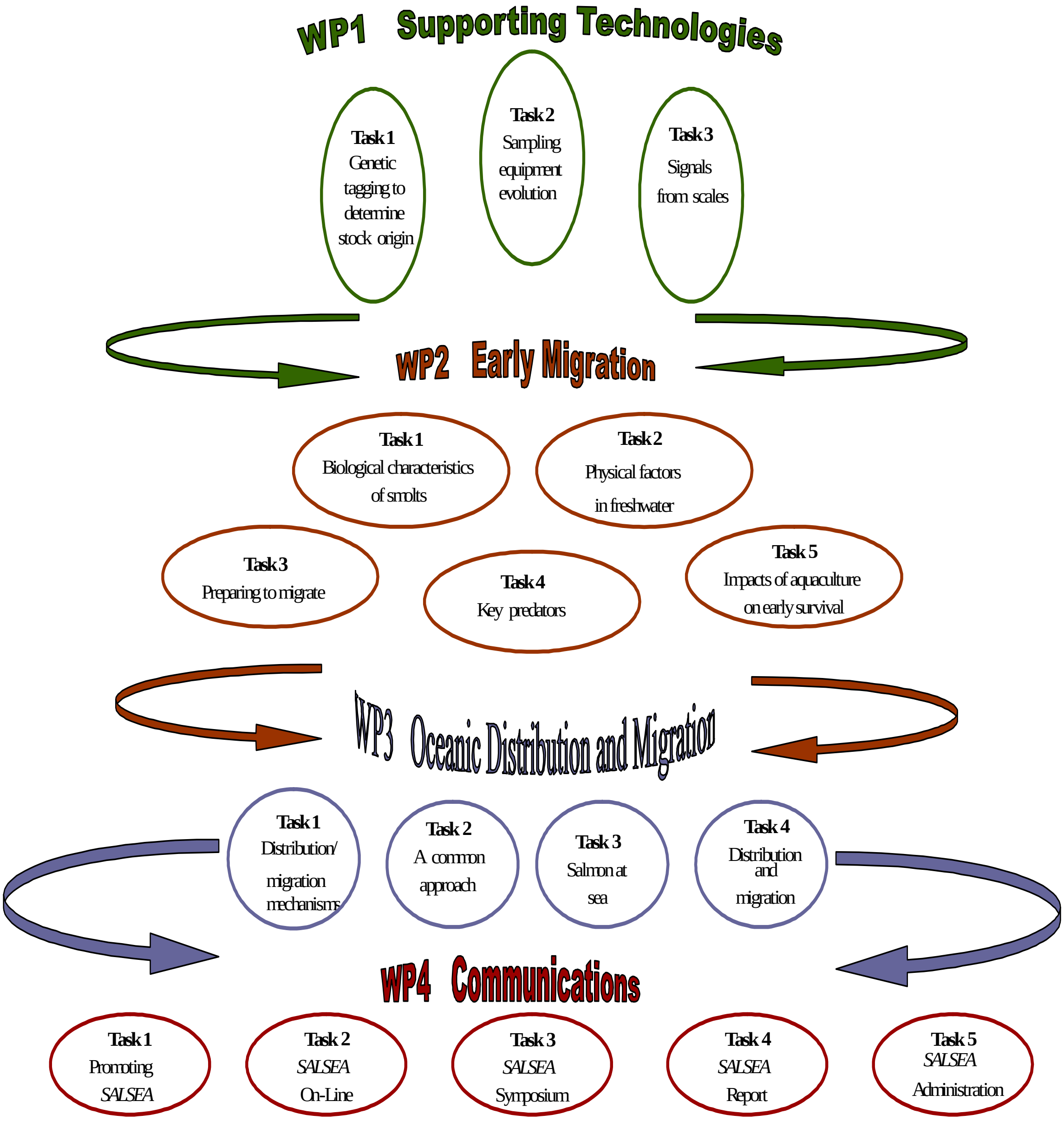
SALSEA is an innovative and ambitious project involving cutting-edge technology, sophisticated information-gathering systems and data analysis in a cooperative effort to unravel the mysteries of the salmon's migrations at sea and the factors influencing this highly prized species. ***SALSEA*** has the potential to capture the public imagination and this aspect of the programme is vital. This Work Package describes how ***SALSEA*** will be promoted to potential funders and how information on the programme and its findings will be disseminated among scientists, managers and the general public. The approaches proposed include:

- development of a fund-raising strategy;
- development of the Board's existing website to include information on ***SALSEA*** and to facilitate exchange of information among scientists;
- implementation of a major international public awareness programme (including web-based approaches);
- convening of a major international symposium to present the findings and consider management implications;
- technical and non-technical reporting arrangements.

The Challenge Ahead

Through research on all stages of the salmon's marine life cycle, ***SALSEA*** will provide a unique insight into life at sea for a long-distance migrant and provide a clearer understanding of the factors influencing the mortality of salmon at sea and the opportunities to counteract them. Success in this endeavour will require coordination of ongoing programmes; additional or redirected core national funding from NASCO's Parties; and additional private sector funding. In the following text, details of each Work Package are presented with a justification for the research, its objectives, the methodology to be employed, timescales for the research and costings. Each Work Package indicates where progress can be achieved through enhanced coordination of existing ongoing programmes, where these programmes would benefit from further support and where new funds would be required for major new research initiatives.

The *SALSEA* Programme



Work Package 1 – Supporting Technologies

Introduction

Great advances have been made over the past decade in a wide range of technologies, which will facilitate the study of the salmon's behaviour, physiology, life history, migration patterns and environmental preferences. Genetic identification, novel post-smolt trawl design and scale analysis are fundamental to achieving the initial objectives of the ***SALSEA*** initiative and should be prioritised for funding. This Work Package contains costed tasks relating to these three key areas but also includes a review of the other supporting technologies which will facilitate the collection of a wide range of quantitative data from individually marked post-smolts (Appendix 1). In particular, further development of archival tag technologies and acoustic sensor arrays is encouraged.

Work Package 1 – Task 1

Genetic tagging to determine stock origin – Map regional genetic structure of Atlantic salmon and establish a standardised genetic baseline database for regional or river-specific populations

Justification

Genetic methods for analysing population structure and distribution have advanced rapidly and their usefulness has been demonstrated repeatedly in a number of species. Genetic Stock Identification (GSI), the use of genetic markers for identifying the proportions of different contributing populations in mixed stock fisheries, has been shown to be a powerful and valuable tool for management of fisheries and has been used in a large number of species, including freshwater, marine and anadromous fish. The best example of this is the management of Alaskan fisheries for Pacific salmon species, where GSI has been used for many years as a practical management tool. The management of the fishery for a local spawning stock of herring in the Trondheimsfjord in Norway is another example of genetic methods being used to distinguish between stocks and the adoption of separate management regimes. With the development of highly variable DNA markers, such as micro-satellites, a finer scale resolution of genetic structure is now possible. With advanced statistical techniques, that exploit the increased amount of information derived from these markers, the multi-locus genotypes of individuals can now be used to assign individuals to their population of origin. GSI methods may be used on their own or in conjunction with traditional tagging methods. Alternatively GSI may augment such studies by providing information on all fish sampled, both tagged and untagged. In the case of electronic data storage tags (DST), GSI and individual assignment methods can also help mitigate under-sampling problems, by identifying region or river of origin of fish tagged in the open ocean, thereby increasing the possibilities for tag recovery. Further, genetic methods can be applied to extract information from sample material already collected (e.g. more than 2,000 samples of salmon from the open seas are in the collections of the Institute of Marine Research, Bergen, Norway; archived scale samples collected over decades exist in collections in countries around the North Atlantic). Such historical data will undoubtedly provide a valuable temporal component to the study.

A significant amount of exploratory work is ongoing to test the potential of individual assignment (IA) methodologies to Atlantic salmon and its applicability for management (King *et al.*, 2001, Koljonen *et al.*, 2002, Booth *et al.*, 2003). Early indications are promising that genetic IA can be successfully applied for the elucidation of questions such as the identification of Atlantic salmon migration and distribution patterns. This contention is supported by work already published on the migration and distribution of a number of species of Pacific salmon. Also, a number of large-scale GSI projects for Atlantic salmon have recently been initiated or are about to begin both in North America and Europe. However, direct comparison of results between these and previous studies will require the standardisation of different sets of markers and scoring protocols. In order to coordinate the research and application of GSI for Atlantic salmon throughout its range a workshop was convened in Sheperdstown, West Virginia, USA under the auspices of the United States Geological Service (Biological Resources Division) in November 2004. The objectives of the workshop were to:

- review existing information on temporal and spatial patterns of microsatellite variation in Atlantic salmon and consider its implications for the use in genetic stock identification (GSI) and for advancing our understanding of the behaviour of the different stocks at sea;
- agree standardised screening methods to develop an international database on microsatellite variation in Atlantic salmon for use in GSI work at local, regional and continental scales.

The proceedings of the meeting in West Virginia will be published in *Reviews in Fish Biology and Fisheries* in due course. The conference was successful in advancing the theoretical basis for an ambitious programme such as ***SALSEA*** and all participants agreed that the techniques to assign mixed populations of juveniles to specific regional areas, or even in some cases to specific catchments, are currently available. Challenges remain in the statistical discrimination of neighbouring or phylogenetically related stocks.

Theoretically it is possible to identify any individual fish captured from either experimental or opportunistic fisheries. However, this assumes that a number of conditions are met. The first of these is that a comprehensive baseline of all, or most, individual stock components can be established. The major task here is to decide what are the constituent building blocks of this baseline. There are at least three levels of population organisation in existence that might be considered. The ***micro-scale*** - a population originating from an individual spawning area or from a specific river tributary; the ***meso-scale*** - a composite of contributing individual spawning population units (i.e. salmon originating from a large river system or geographical area, an individual country or from ICES-designated Northern or Southern European stock complexes); the ***macro-scale*** - fish originating from different continents. At present in some locations it is possible to assign individuals to both macro- (North American sampling programmes at West Greenland) and micro-scales (Irish studies in Moy and Foyle river catchments) with a high degree of confidence. There are some issues to be resolved in order to have an effective programme at the regional level (e.g. what proportion of populations within a region have to be sampled in order to establish a composite genetic profile). This treatment might not be the same for all regions. The second assumption is that the established baseline is temporally stable. This might be reconciled by examining archive biological material such as scale material, or by re-sampling contributing baseline populations on an ongoing basis.

Given that these assumptions can be met, genetic individual assignment has the following advantages:

- the analysis is based on the behaviour of wild fish thus overcoming the experimental error introduced by either handling wild fish or using hatchery fish as a surrogate for wild salmon. There are significant dangers, such as potential genetic introgression into natural populations, associated with large-scale hatchery release programmes;
- all individuals captured in the experimental fisheries are of equal value and can be used in subsequent analysis. This provides a significant cost advantage over conventional tagging where only those individuals that have tags can be used;
- all samples previously collected from marine surveys (historic archives of scales/otholiths, etc.) can be analysed. These data can be used in elucidating temporal trends in migration and distribution patterns.

Objectives

- Review existing knowledge of genetic structure within the distribution area of Atlantic salmon, and establish an overall picture of population structure;
- Compile an inventory of available samples, both recent and historical, that could be used in a larger-scale mapping of genetic structure;
- Establish a cooperative programme between the principal genetic laboratories in Europe and North America to screen the major salmon stocks. This will be accomplished by selecting a suitable array of genetic markers, based upon the level of variation observed in previous studies and calibrating the scoring between participating laboratories;
- Based on the results from the above studies select an experimental set of populations to be sampled;
- Review the results and determine whether sufficient precision is achieved for the purposes outlined in the core ***SALSEA*** tasks. Expand and include more areas and populations in the baseline as required;
- Establish a standardised database of genetic structure of baseline populations;
- Carry out comparative studies using conventional tags of known origin to provide support for genetic identification;
- Establish a "Biobank" of samples collected, and also of DNA extracts that can be made available for other purposes at later stages.

Methodology

The work should be initiated by reviewing existing relevant programmes, including the recently completed EU programme (***SALGEN)***, and carrying out a full literature review. A major planning workshop should be held to standardise genetic analysis techniques and scoring and to compile an inventory of available sample material for establishing baseline data.

The planning workshop would determine the following:

- What is the scientific basis for deciding what is a biologically significant population unit?

- What are the logistical considerations involved in collecting samples that are representative of the entire range of the species (potentially thousands of biologically significant population units)?
- How best to compile a hierarchical, strategic sampling regime which will provide the most effective and economically efficient sampling programme;
- Can samples be aggregated to be representative of regional or political entities?
- What suite of markers should be used?
- Where should/can genetic analyses be undertaken (Universities, Government Institutions, Industrial processors, etc.)?;
- What protocols should be used to analyse and report data?;
- What arrangements should/can be made for the management of the data (legal, intellectual property (IP) and patenting issues)?

As there may well be some issues relating to the use of genetic information collected collaboratively and on an international basis, the IASRB could act as an independent repository for genetic information on different stocks and as an arbitrator of standards and methodologies.

Timescale

We are fortunate that some baseline data already exist. It is envisaged, however, that if the coordination as outlined above is successful then the range and precision of this baseline will gradually increase. A fully established comprehensive baseline enabling individual assignment for every captured fish will require between 5 and 10 years to develop. In order to achieve the best value for money in the short to medium term it will be necessary to objectively assign individuals to the largest and most productive biological entities. Critical to the success of this approach will be validating the assumption that it is appropriate to aggregate genetic data from a proportion of populations within a region to establish a composite genetic profile.

Coordination Timescale

- Planning, securing agreement of main participants and holding of major planning workshop: 12 to 18 months;
- Laboratory optimisation and standardisation: 12 months.

Work Package 1 – Task 2

Sampling equipment evolution to increase the sampling efficiency for salmon at sea

Justification

Since 1990 there have been encouraging advances in our understanding of migration routes of salmon and their distribution at sea (Reddin and Short, 1990, Holst *et al.* 1993, 2000. Holm *et al*. l996, 2000, 2003. Shelton *et al*. 1997, 2000; Jacobsen 2000). This has been facilitated by the development of survey techniques and survey designs, which have resulted in the ability to obtain samples of post-smolts and adults consistently in areas where these were not previously available. The development of new survey techniques has the potential to greatly improve our existing understanding of migration and distribution. Further evolution of sampling equipment might include development of: large area screening trawls;

an open trawl digital observer/analyser; an open trawl pit tag detector; an open trawl live sampler; methods for the large-scale capture of migrating wild smolts (see Appendix 1). It has been shown that Atlantic salmon trawl data have a significant size bias resulting from a strong positive size selection for the smaller individuals. Trawl surveys consistently over-represent smaller salmon. Efforts should be made to remove this size bias for datasets to more accurately reflect the true population dynamics. This task is considered to be of immediate importance and should be top priority for research and development teams working in these types of programmes.

Objective

Initiate research efforts to develop smolt trawl design to minimise size selection.

Methodology

A major challenge, prior to initiating a large open-ocean sampling programme, will be the development of appropriate sampling methods to collect all size-classes of salmon encountered during the survey. A research and development programme is urgently required to develop trawl gear which minimises the size selectivity currently observed in post-smolt and adult trawls. Such a programme will require a two-year development and testing phase in advance of any major open-ocean surveys.

Timescale

This task should be initiated as soon as possible so as to ensure development of experimental designs in 2005 and initial ocean testing in autumn/early winter 2006.

Participating Countries

Norway, Iceland, Faroes, Canada, UK and United States.

Potential Products

Improved trawl designs for collecting data on the full size spectrum of salmon likely to be encountered during the high seas and near-shore programmes.

Work Package 1 – Task 3

Signals from scales – Establish standardised scale analysis techniques and identify marine growth histories and anomalies indicating common mortality factors on spatial and temporal scales

Justification

There is a considerable collection of historic scale material available from most salmon-producing countries and, as outlined above, these now form a unique historic genetic resource. The growth data contained on these scales also provides a valuable record, and analysed marine growth histories may be compared with changes in the marine environment over recent decades. However, the first requirement in analysing these scale collections and comparing results between countries is to ensure the use of standardised scale analysis procedures between laboratories. Recent developments in digital analysis hardware and software have resulted in a significant advance in this area. The establishment of a digital scale library, with associated scale morphometrics, would significantly improve the capacity to analyse these scale collections. This in turn would allow scientists to analyse marine growth histories on a standardised basis and to compare these with changes in the marine environment over recent decades.

Objectives

- Ensure that results from scale analysis equipment in selected European and North American laboratories is comparable;
- Carry out scale analysis training for all participating laboratories by North American experts while ensuring that agreed-upon standardised scale examination procedures are being followed;
- Carry out scale analyses on selected scale sets with a view to establishing a comparable database between laboratories;
- Coordinate the examination of scale material available from several research agencies (or from different stocks and stock components) to identify spatial and temporal anomalies in the time series of scale growth during the marine phase, which may indicate common causes or factors influencing mortality at sea.

Methodology

Equipment and software will be selected and installed in two major research laboratories in Europe currently analysing scale samples for marine growth analyses. Equipment and software in North American laboratories will be upgraded to that available in the European laboratories. Training will be conducted by North American scale analysis experts on the proper use of scale analysis while following agreed-upon standardised procedures. Representative scale samples will be selected from each country and from each decade going back in time as available. A summary of the available samples will be provided to the participating countries. The processing of these samples will be coordinated by the selected laboratories. A major Workshop will be convened to evaluate the dataset from a North Atlantic perspective looking for correlated responses in marine growth trajectories. This Workshop might be organised by ICES, which has held a number of scale-reading workshops.

Timescale

This element of the ***SALSEA*** initiative should take place over an 18-month period. The equipment purchasing, training, sample collation and processing should occur in the first year (2005) and the Workshop should take place at the end of 2006.

Participating Countries

Representatives from all countries with historic scale data.

Potential Products

Insights into historic marine growth trajectories in time and space relative to environmental conditions.

Work Package 2 – Early Migration through the Inshore Zone: fresh waters, estuaries and coastal waters

Introduction

The factors affecting marine survival of salmon in the inshore zone include: those operating in fresh water which influence the fitness of emigrating smolts during the marine phase; transitional factors which affect the ability of fish to move from fresh to saline water (or return); and anthropogenic factors operating within the coastal zone. In contrast to the open ocean, it may be practical to follow the movements of significant numbers of individual fish through the inshore zone, using active or passive tracking methods and to quantify the losses of fish. Research in the near-shore zone therefore offers the possibility of localising the areas where losses occur and consequently identifying the causes.

The factors operating in this zone will tend to have more local or regional effects than those operating in the open ocean, which may be expected to affect stocks from a wider range of rivers. However, some of these factors may still be contributing to the critical decline of stocks in many areas. The key purpose of this area of work is to facilitate, through coordination and additional funding, concurrent studies of these issues at strategic sites on both sides of the Atlantic.

A great deal of research is currently ongoing in transitional waters or in the near-shore zone. This research is largely funded by national agencies or partnerships with national agencies and it is envisaged that this will continue to be the case. This Work Package identifies areas where there is a need for further work and greater coordination.

Work Package 2 – Task 1

Investigate the influence of biological characteristics of Atlantic salmon smolts on their marine mortality

Justification

There is a substantial body of research which demonstrates that the freshwater and marine environments cannot be considered in isolation. Studies have shown that the biological characteristics of Atlantic salmon smolts which may be determined by condition is freshwater may affect their subsequent survival in the sea. Thus, for example, studies have also shown that mean smolt length at age is affected by factors operating in fresh water, such as juvenile density (Gardiner and Shackley 1991, Korman *et al*., 1994, Orciari *et al*., 1994). There is also evidence that survival of smolts at sea is size-dependent (see summary in Hansen and Quinn 1998), and other factors such as time of entry into the ocean (Dempson *et al*., 1998) may also be influenced by size (larger smolts leave first) and so may be associated with variations in marine survival. Body size could be important for several reasons, including an ability to osmoregulate, avoid predators, or find prey of an appropriate size, and is one of a number of biological characteristics which could be important (Gardiner and Shackley 1991, Korman *et al*. 1994, Orciari *et al*. 1994).

The aim of the proposed research is to develop this work more comprehensively around the North Atlantic and determine if recent decreases in survival can be attributed to factors in fresh water affecting the biological characteristics of the smolts.

Objectives

The overall aim is to identify differences in the marine survival of smolts with different characteristics, and determine the extent to which such factors could account for widespread changes in salmon stock abundance.

The specific research objectives are to:

- Identify the key biological variables among smolts that may affect marine survival and evidence of widespread changes in these characteristics in stocks;
- Determine the impact of smolt characteristics on migratory behaviour;
- Determine the impact of smolt characteristics on marine survival and return of spawning adults;
- Model the impact of smolt characteristics at the population level;
- Determine management options.

Methodology

Research will proceed by reviewing historical data from monitored rivers. Evidence will be sought of differences in survival rates for both wild and hatchery-reared smolts showing different characteristics by the smolt size distributions of emigrating smolts and the surviving adults from the same cohort. Where tracking programmes are underway, survival results will be assessed in comparison to different smolt characteristics, such as size, condition, and sex.

In rivers where relevant historical information on the size of smolts is not available, returning adult scales will be analyzed by back-calculating smolt size, and assessing this in relation to periods of time when salmon abundance and/or fishery exploitation regimes have changed.

To further develop this work, there will be a need for more monitored rivers, especially in Europe. Archived datasets as well as results from ongoing or new studies will be coordinated with emphasis being placed on strategic areas on both sides of the Atlantic. A network will be established for research groups who are already funded and working in this area, in order to promote complementary studies, avoid duplication and identify research gaps and opportunities. Additional funding will be sought for seeding studies and comparative studies.

Timescales and timelines

Three years of laboratory and data analysis, and review of findings at a workshop.

Work Package 2 – Task 2

The impacts of physical factors in fresh water on marine mortality of Atlantic salmon

Justification

Physical conditions experienced by Atlantic salmon smolts within fresh water may be critical to their subsequent survival in the sea. For instance, water flow and water temperature, both of which may be mediated by climate change, can modify growth, inhibit or delay smolt emigration, reduce sea water adaptation and marine survival, and influence maturation. Furthermore, evidence from North America and Ireland suggests that survival may be affected by the transitional conditions, such as temperature, between fresh and saline waters.

The physical conditions experienced by returning salmon in inshore and estuarine areas may also affect survival. For example, during periods of low flow, Atlantic salmon may not be able to ascend rivers for many weeks, potentially increasing exposure to fisheries, aquaculture and predation.

There already exists a wealth of information from monitored rivers on many of the freshwater factors affecting subsequent marine survival but this has not generally been brought together for joint analysis.

Objectives

The overall aim is to assess the effects of physical variables on marine survival. The goal is to identify common or differing trends in freshwater physical conditions that are common throughout the geographic range, or within a geographic region, and that may modify factors such as smolt quality or migratory behaviour and reduce the ability of smolts to physiologically adapt to the marine environment.

The specific objectives are to:

- Determine the impact of physical variables at the time of smolt emigration on survival to the open ocean (i.e. to adapt to sea water conditions and thrive and grow in marine conditions and return to natal fresh water to breed) (Sub-task 1);
- Determine the impact of key physical variables, such as temperature, flow, turbidity, on the run-timing of wild salmon smolts and consequent survival to the open ocean (Sub-task 2);
- Determine the impact of physical variables on behaviour of smolts during the transition between the freshwater and marine environments and on the abilities of smolts to survive the transition from fresh to sea water (Sub-task 3);
- Determine impacts of coastal transition waters on survival of returning adults into the river (Sub-task 4);
- Model the impact of freshwater physical variables on Atlantic salmon at the population level (Sub-task 5);
- Determine management options for mitigating impacts (Sub-task 6).

Methodology

The principal requirement to achieve this aim is to establish a network between the research groups who are already funded and working in this area; promote complementary studies, avoid duplication and gain from cooperative planning and analysis of existing data. Funding is required for coordination of programmes and data analysis by establishing working groups, and joint studies, for seeding new studies and to fill gaps in existing research. Archived datasets as well as results from ongoing or new studies will be used. The methodologies associated with each of the sub-tasks which address each of the objectives will be elaborated at the first workshop (see timescales and timelines below).

Timescales and timelines

A first task is to prepare an inventory of completed and ongoing research (6 months). A workshop would then be held in order to synthesise results and coordinate ongoing and future work and/or develop an integrated research programme that would address the various sub-tasks. The workshop, over a period of one week, would also consider the adequacy of the existing network of sites on both sides of the Atlantic and consider whether the network needs to be expanded. A systematic programme of work, based around the monitored network of rivers, would extend to many years, although it is envisaged that a second workshop, held after a three-year period, would provide answers or indicators as to the importance of many physical variables on survival. A final workshop, together with a published report, including management advice for mitigation, would be produced at the end of Year 5.

Timescale

An indicative time-scale is 5 years.

Work Package 2 – Task 3

Preparing to migrate – investigate the influence of freshwater contaminants on the marine survival of Atlantic salmon

Justification

Recent research has demonstrated that exposure of juvenile salmon in fresh water to environmental levels of contaminants such as pesticides, endocrine-disrupting chemicals (EDCs) and acidification/aluminium may operate to reduce survival in fish once they experience saline conditions (Madsen *et al*., 1997; Fairchild *et al*., 1999; Fairchild *et al*., 2002; Krogland & Finstad, 2003; Magee *et al*. 2003; Moore *et al*., 2003; Waring & Moore, 2004). Exposure to sub-lethal levels of these contaminants can modify growth, inhibit or delay emigration, reduce seawater adaptation and result in poor survival once the fish have moved into marine conditions. Many such contaminants are very widely used in regions with salmon rivers and may be having widespread effects on return rates in these stocks.

Salmon may also be impacted by contaminants on their return migration through coastal waters, and it may be necessary to develop further programmes to address these problems as a follow-on to the work outlined in this Task.

Objectives

The aim of this programme is to assess the effects of freshwater contaminants that are common throughout the geographic range of Atlantic salmon, on marine survival and their potential role in the widespread decline of stocks.

The specific objectives are to:

- Identify freshwater contaminants that are common throughout the geographic range of Atlantic salmon and that might be expected to modify migratory behaviour and/or reduce the ability of the smolts to physiologically adapt to the marine environment;
- Determine the effect of environmental levels of the target contaminants on the parr-smolt transformation and the ability of smolts to survive in marine conditions;
- Determine the impact of the target contaminants on run-timing of wild salmon smolts and the migratory behaviour of smolts during the transition between the freshwater and marine environments;
- Determine the impact of target contaminants on marine survival and return of spawning adults;
- Model the impact of freshwater contaminants at the population level;
- Provide management options for resolving impacts identified in these studies.

Methodology

Sub-task 1: Identifying freshwater contaminants

A desk study will be carried out to identify contaminants that are common throughout the geographic range of the salmon and, in particular, where stocks are showing significant declines in marine survival. The study will utilise water quality monitoring data from Government and other Agencies to identify target contaminants and their environmental levels. The study will also identify those contaminants whose structure and mode of action are likely to significantly modify the processes involved in the parr-smolt transformation when the fish become physiologically, morphologically and behaviourally adapted to survive in the marine environment.

Studies will be coordinated between all countries in Northern Europe and North America in order to collate available information from respective national environmental water quality monitoring databases. The information provided should include a list of persistent chemicals which occur regularly during the parr-smolt transformation in watercourses supporting populations of spawning salmon. The main objective will be to select 1 or 2 target contaminants for further investigation using the following selection criteria:

- Common to the majority of salmon-producing countries;
- Occur in rivers supporting salmon populations;
- Occur during the parr-smolt transformation;
- Toxic mechanism is linked to modifying smolt physiology and behaviour.

Timescale

6 months.

Sub-task 2: Effects of contaminants on parr-smolt transformation

Laboratory-based studies will be carried out to determine the impact of the target contaminants on the parr-smolt transformation and the ability to survive in marine conditions. Groups of smolts will be exposed to environmental levels and periods of contaminants and physiological biomarkers for smoltification measured (e.g. gill Na^+K^+ATPase activity; plasma ions; T_3 and T_4; insulin-like growth factor-I ~ IGF-I; plasma cortisol; condition factor). Fish will then undergo 48-hour seawater challenge tests to determine their subsequent ability to survive in marine conditions. The work will be carried out under strict experimental protocols in at least three different laboratories and all samples analysed using the same reproducible methodologies.

Participating Countries

England, Canada, Denmark, Norway, Ireland.

Timescale

24 months.

Sub-task 3: Effects of contaminants on migratory behaviour and distribution

Field-based studies will be carried out in experimental streams and indicator rivers to assess the impact of exposure of juvenile salmon to target contaminants on run-timing and freshwater migratory behaviour in both Europe and North America. Groups of fish will be marked (e.g. PIT tagged) and exposed to environmental levels of contaminants for periods during the parr-smolt transformation. Fish will then be released into the river and their movements monitored (e.g. using fixed PIT detectors within the river close to the tidal limit). Fish from each group will also be sub-sampled to measure the physiological biomarkers for smoltification described above. The behaviour of the fish will be related to physiological status and contaminant exposure.

Potential network of participants: Experimental streams in Alvkarleby, Sweden; monitored rivers with PIT systems in England; monitored rivers with PIT systems in Denmark, Norway, Ireland and Canada.

Timescale

24 months.

Sub-task 4: Effects of contaminants on smolt behaviour and distribution

Field-based telemetry studies will be carried out to assess the impact of target contaminants on the behaviour and distribution of post-smolts within the estuarine and near-coastal zone. Groups of juvenile salmon will be exposed to environmental levels of target contaminants as described above. Prior to release, fish will be tagged with miniature acoustic transmitters and their subsequent distribution and migratory behaviour monitored using both fixed arrays of acoustic receivers and active tracking from a small research vessel. Fish from each group that are not tagged will be sub-sampled to measure the physiological biomarkers for smoltification described above. The behaviour and distribution of the fish will be related to physiological status and contaminant exposure. The work will be carried out at three sites using the same tagging protocols and tags.

Participating Countries

England, Denmark, Norway, Scotland, Ireland, Iceland, Canada.

Timescale

24 months.

Sub-task 5: Effects of contaminants on adult return rates

Large-scale release studies of micro-tagged fish exposed to environmental levels of target contaminants as described above will be undertaken. The tagged fish will be monitored as part of ongoing sampling programmes in the open sea and home waters to determine the differential survival of the fish and the potential impact of contaminants. The study will utilise hatchery-reared fish as exposing large numbers of wild fish to contaminants is not acceptable. Fish from each group that are not tagged will be sub-sampled to measure the physiological biomarkers for smoltification described above. The physiological data will be correlated with the subsequent survival of the fish. The work will be carried out at three sites using the same tagging protocols and tags. Potential locations include: England, Denmark, Norway, Ireland, Iceland.

Timescale

48 months.

Sub-task 6: Modelling impacts at a population level

The results of the laboratory- and field-based research will be used in existing Atlantic salmon life-history models to predict the impact of environmental levels of freshwater contaminants at the population level. A desk study will be undertaken to model the impact of exposure to freshwater contaminants on populations of Atlantic salmon using life-history models.

Timescale

9 months.

Work Package 2 – Task 4

The part played by key predators

Justification

Predation on out-going smolts and returning adults has potential to have major impacts on populations, but data are insufficient to confirm or refute this view. The marine phase of Atlantic salmon begins when juvenile salmon become smolts, a transition which occurs in fresh water. Smolts are vulnerable to predation as they descend rivers and as they pass through estuaries on their way to the sea. Their main potential predators include birds such as cormorants and mergansers, piscivorous fish such as pike and cod, and mammals such as seals. Adults returning from the sea may also be vulnerable as they are concentrated as they transit estuaries, where they also face predation risk from seals.

Objectives

The overall aim is to determine the contribution of predation by key predators to the marine mortality of salmon.

The specific objectives are to:

- Determine the proportion of out-going smolts and returning adults that are removed by predation, to identify the predator(s) involved, and to determine the time, location, and circumstances of this predation;
- Compare current patterns and intensities of predation with the situation prior to the salmon decline.

Methodology

Predator diet studies and combined predator and prey studies will be conducted at selected sites across the range of latitudes on both sides of the Atlantic. Measurement of scarring rates will be added to existing monitoring programmes for returning adult salmon.

Diet of potential predators will be examined by conventional stomach analysis, and by examination of scats and regurgitations for the presence of otoliths, physically identifiable remains, and tissue, which can be identified by DNA analysis.

In selected sites, movements of exiting smolts and/or incoming adults can be tracked. Tracking will take place by research fishing, or by monitoring of sonic tags with boat-mounted receivers or bottom-deployed arrays. Movements and distribution of seals, seabirds, and piscivorous fish will be simultaneously examined. Quantitative estimates of survival of salmon to specific points along the migration route can be obtained from some technologies (e.g. sonic tracking). This information can be matched to factors in specific areas (e.g. predator concentrations), to infer causes of mortality.

Salmon which survive attacks by seals and other predators often bear scars. Scarring rates do not directly indicate predation, because scarred individuals are survivors, not victims. However, scarring data can give a valuable indication of geographic and temporal trends in predation on returning adults. Thus the aim will be: to develop reliable means of identifying the predators which cause scar marks by examining the physical structure of predator mouths and teeth in comparison with observed marks; to establish standard protocols to record presence/absence and characteristics of predator scars on returning salmon seen at in-river trapping stations and other monitoring schemes; and to use the Marshall method (Cairns 2001) to calculate from scarring rates the minimum predation mortality rates on 1-sea-winter and 2-sea-winter fish.

Timescales and timelines

36 months.

Work Package 2 – Task 5

The impacts of aquaculture on mortality of salmon

Justification

Farming of salmon has developed rapidly over the past 25 years. In 2003, some 800,000 tonnes of farmed salmon were produced in the Atlantic area. In comparison, the total nominal landings of salmon in capture fisheries in the North Atlantic were about 2,500 tonnes the same year. Salmon farms are situated in fjords and on the coast in areas where wild salmon are present for parts of the year. Salmon escape from fish farms at all life stages and are caught in oceanic, coastal as well as freshwater fisheries and spawn in fresh water, but their reproductive success is lower than for wild salmon.

The spread of fish farm escapees into areas of the North Atlantic, where wild salmon are also found, raises several potential problems. Firstly, assessments and management of salmon fisheries and wild salmon stocks will be complicated in the presence of high numbers of farmed salmon and it is therefore of great importance to identify farmed fish and adjust catch records accordingly. Secondly, it has been demonstrated that hybridization between farmed and wild salmon may have negative impacts on wild salmon (McGinnity *et al.*, 2003). Thirdly, salmon farms and escaped farmed salmon may be vectors for transferring diseases and parasites to wild salmon as well as attractants to predators. Sea lice infestations have been documented to be a significant problem in some areas.

If sea lice infections are not controlled in fish farms, large number of larvae will be spread into the sea, and may infect wild salmon smolts passing through the area at the same time. The lice may cause direct mortality on smolts, or stress the fish so they may be highly vulnerable to predation. Sea lice may occasionally pose a problem for returning adults, particularly if their homeward migration is delayed in salt water due to low flows in rivers. Recent research has also indicated that transfer of lice to adult salmon in the feeding areas may be an important issue to be addressed.

The continued expansion of fish farming to alternate species and, in the case of salmon farming, its growth to offshore areas, may pose new challenges to wild Atlantic salmon populations. Cod farming has begun in both the Eastern and Western Atlantic regions. Cod are predators of wild Atlantic salmon, and their escape from farms into salmon areas, or the presence of cod odour plumes across the migration routes of migrating smolts, could negatively impact wild populations. Similarly, massive expansion of salmon farming to offshore areas could increase the numbers of escaped farmed salmon present in the ocean, and may lead to presently unanticipated impacts.

Objectives

Given that a considerable amount of new information on interactions between aquaculture and wild Atlantic salmon is now available, NASCO and ICES are holding a symposium in Bergen, Norway, 18-21 October 2005 on 'Interactions between aquaculture and wild stocks of Atlantic salmon and other diadromous fish species: Science and Management, Challenges and Solutions'.

The objectives of the symposium are:

- To summarise available knowledge on the interactions between aquaculture and wild stocks of Atlantic salmon and other diadromous species;
- to identify gaps in current understanding of interactions and develop recommendations on future research priorities;
- to review progress in managing interactions of aquaculture, the challenges that remain and possible solutions;
- to make recommendations for additional measures, including cooperative ventures between the various stakeholders, to ensure that aquaculture practices are sustainable and consistent with the Precautionary Approach.

This symposium will summarise the information currently available on this important topic and outline key future research areas. This will provide the basis for defining more precisely the research requirements in this area.

Work Package 3 – Investigating the Distribution and Migration of Salmon at Sea

Introduction

This Work Package outlines the framework for a comprehensive, multi-disciplinary, survey of post-smolts across the North Atlantic. This survey is required to collect data fundamental to determining the migration and distribution patterns of Atlantic salmon at sea. This is an essential pre-requisite to identifying the biotic and abiotic factors in the sea that directly influence marine survival of salmon.

Such a survey programme will be a major undertaking and must therefore be approached in stages. The first step will be to ensure that the best use is made of all existing survey, tracking and tagging results, along with knowledge of salmon migrations, in order to develop hypotheses about salmon distribution and behaviour which can be tested (Work Package 1). The programme is expected to involve a number of vessels, so techniques and approaches for the surveys must be standardised (Work Package 2). This Package also lays out the theoretical groundwork for the coordination of a major, international, multi-disciplinary survey of the North Atlantic and a methodology for analysing and summarizing the survey results. The marine survey will then be used to collect the samples and information required to compare migration patterns, distribution and possible factors affecting survival of reared and wild salmon post-smolts at sea (Work Package 3). Finally the results from the surveys will be used to model the possible effects of biological and physical oceanographic factors on the migration and distribution of salmon (Work Package 4). This Work Package follows logically from tasks previously outlined in Work Package 1, which include work: to modify and test the specialised trawls to allow for sampling across the size range and ages of the entire salmon population; to establish a standardised genetic baseline database for regional or river-specific populations; and agree to standardised scale analysis techniques and undertake analysis of marine growth histories and anomalies which may indicate common mortality factors on spatial and temporal scales.

By-catches and non-catch fishing mortality of post-smolts have also been identified as potential major causes of mortality of salmon in the sea. This issue is currently being investigated by an ICES Study Group on By-catch of Salmon (SGBYSAL) which is examining catch information from pelagic fisheries in relation to salmon migrations and the issue of scanning and sampling for salmon post-smolts in these catches. Once the results of these studies are available, SALSEA will plan appropriate field studies as required to test and validate the findings.

Work Package 3 – Task 1

Distribution and migration mechanisms - Develop theoretical migration models from existing studies to facilitate surveys and provision of advice for contemporary migration and distribution theory testing

Justification

One of the main drawbacks to surveying salmon at sea is the relatively small number of target animals relative to the potential area of migration. It is, therefore, essential that the initial focus should be on refining our current migration and distribution knowledge to improve the resolution of the proposed marine sampling tasks. This will be designed to increase the efficiency of sampling, optimal use of survey equipment and a significant reduction in costly ship time. This work will be based on available biological and oceanographic data. In recent years, there has been a significant increase in the availability of large oceanographic and meteorological databases with easy access through the World Wide Web. This has led to a proliferation of studies relating to the production and distribution of important marine organisms to physical parameters such as sea surface temperature, currents, wind speed, wave action, salinity, etc. In line with these developments, studies are currently in progress in several North Atlantic salmon-producing countries, which make use of this vast wealth of on-line data.

Objectives

- To assemble all available scientific data, both near-shore and open ocean, on post-smolt distribution, migration, growth and feeding at sea;
- Review current investigations using oceanographic data so as to refine/develop predictive tools for assessing marine thermal habitat preferences and possible oceanic migration paths;
- Test the hypothesis that distribution and stock composition are stable over time by examining time series of oceanic and home-water tag recoveries and from scale sampling programmes;
- Review the existing information on differences in the behaviour and survival of hatchery and reared salmon at sea.

Methodology

A working group will be formed, comprising the key researchers in this area, to coordinate the assembly of all relevant post-smolt data, and a major workshop will be convened to review these data and to plan the theoretical basis for the open-ocean survey programme.

Timescale

This work will take 12 months to complete. The Workshop should last 5 days and should be one of the first initiatives in year 1 of ***SALSEA.***

Participating Countries

Representatives from all countries with relevant post-smolt data.

Potential Products

- Best estimate of post-smolt migration routes to assist in planning the open-ocean survey;
- Provide advice on strategic open-ocean sampling locations and targets for optimal smolt sampling at sea.

Work Package 3 – Task 2

A common approach – Refine the plans for a large-scale marine survey programme and standardization of trawl survey techniques between the participating partners

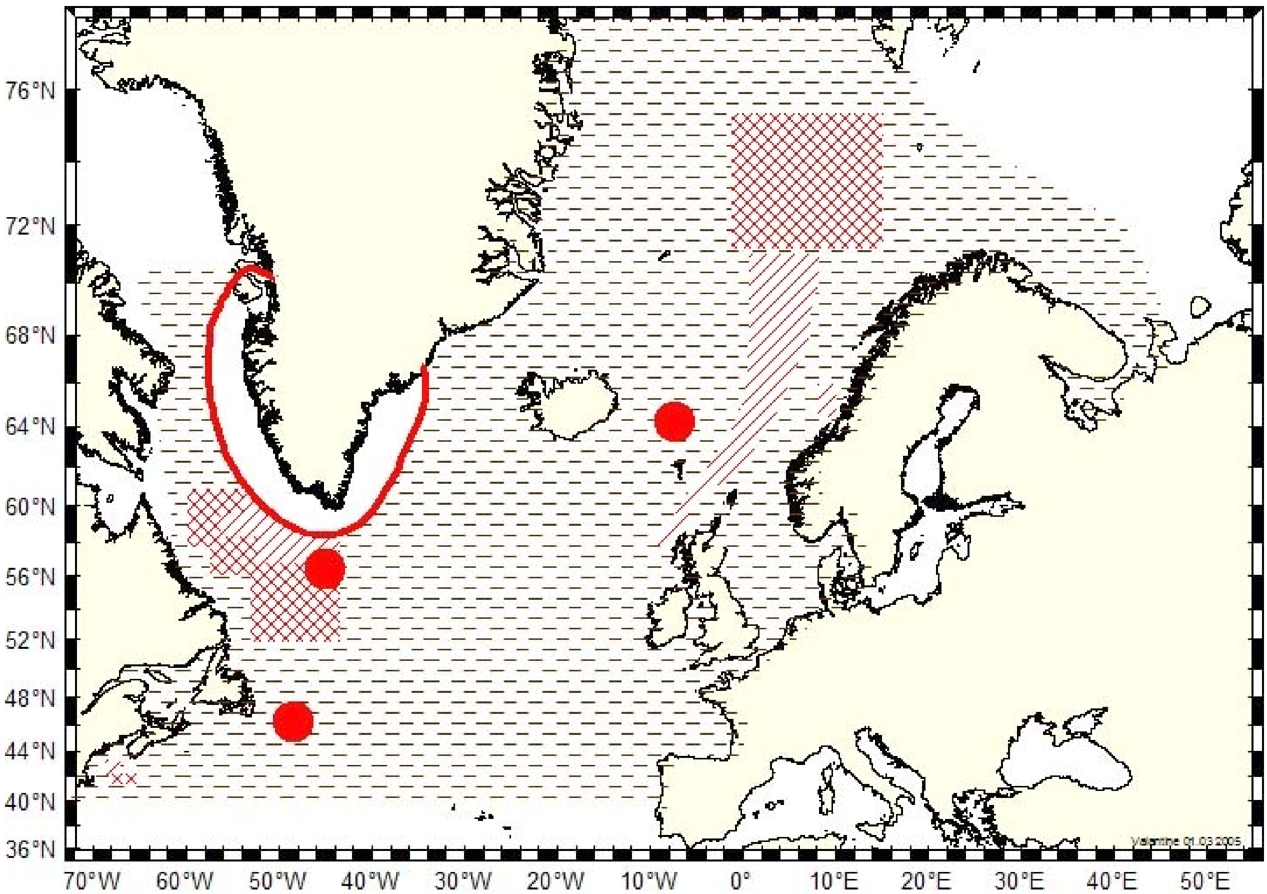
Justification

There is a varying degree of knowledge on salmon distribution in the North Atlantic. This information was historically obtained through tagging/recapture studies and more recently through analysis of independent trawl survey data. The summarization of this information has enabled researchers to develop a composite sketch of the distribution of Atlantic salmon post-smolts at sea (Figure 1). The results of the modelling exercises in Task 1 will allow researchers to concentrate the planned survey efforts in areas of presumed high salmon densities. However, the previous surveys have been developed independently and standardised operating procedures need to be developed before a coordinated international research programme can be initiated. The planning phase of this ambitious programme will need to be both detailed and fully comprehensive. Such a major programme will require the support of a full-time manager and a small Secretariat (see Work Package 4).

Objectives

To develop Standard Operating Procedures and plan the large-scale marine survey programme.

Figure 1: Recorded and unknown areas of distribution of post-smolts and adult Atlantic salmon in the North Atlantic outside of coastal migration routes derived from research and commercial vessels fishing at sea. Hyphens depict the area from which there are no consistent records of fish but is within the assumed range of the salmon in the sea based on the salmon-producing rivers around the North Atlantic. Inshore distributions of adults and post-smolts are not included.



Legend: *Diagonal hatching: high densities of post-smolts recorded at certain time periods. Cross diagonal hatching: post-smolts recorded, but in lower densities. Filled circles: high densities of adult fish recorded. Solid line: Only salmon that would have returned to rivers as 2SW salmon or older are caught within this area.*

Methodology

A coordination meeting of key samplers will be required to plan the main research surveys at sea, select the areas to be surveyed and agree on the methods to be employed during the survey. Such an approach will ensure the close coordination of the various components of the programme in the east and west Atlantic and ensure that the results are directly comparable.

As an output from the coordination meeting a *Trawl Standardization Working Group* will be established to assign project leaders and responsibilities for key studies and develop standardised procedures for all aspects of a trawl survey including:

Trawl Gear

Data collection
Ship recording
- Towing logistics (location, speed…)
- Environmental variables (wind, sea state…)
- Biological observations (predator presence…)

Oceanographic/physical/chemical data
- Temperature, salinity, primary/secondary productivity, currents (ADCP), pollution …

Co-occurring species
- By-catch, predator/prey observations from vessel, secondary sampling (plankton, zooplankton, krill hauls…)

Biological data
- Genetic samples
- Growth-related samples
- Feeding-related samples
- Physiology
- Parasitology

Tag recovery procedures for all tag types available

Appointment of ***SALSEA*** manager, secretariat and coordination of a series of detailed planning meetings.

Timescales

Main planning meetings should be scheduled for a six-month period prior to first marine survey (target dates late 2007/early 2008).

Participating Countries

Representatives from all countries participating in the trawl surveys, especially Principal Investigators presently conducting such surveys and Principal Investigators scheduled to conduct such surveys as part of ***SALSEA***, together with the ***SALSEA*** manager.

Potential Products

Full planning of Atlantic salmon trawl survey of defined zones within the North Atlantic.

Work Package 3 – Task 3

Salmon at sea - Carry out a comprehensive marine survey to collect samples and information required to compare migration patterns, distribution and possible factors affecting survival of reared and wild salmon post-smolts at sea

Justification

The overall objective of the ***SALSEA*** initiative is to identify the potential factors influencing salmon distribution and migration patterns (e.g. ocean parameters, prey availability, competitors and predators). This will depend initially on studying the migration and distribution of salmon post-smolts over a large area of the North Atlantic. Genetic techniques (Work Package 1) will be used to identify the bulk of the salmon sampled to at least region of origin; however, all participating parties will be encouraged to optimise the number of tagged fish released in the years of the open-ocean programme so as to ensure that finer-scale information on individual fish is collected. Tagged fish will also provide a key control to test the accuracy of the genetic assignation by stock.

This work package comprises the core element of ***SALSEA*** and will involve a major trans-national, multi-disciplinary survey equipped with state-of-the-art survey equipment, tagging methods and analytical tools. The major challenge will be to consistently locate and sample salmon in selected areas of the North Atlantic and to relate these findings to stock origin and prevailing oceanic and biological conditions.

However, a considerable amount of Work Package 3 will have been spent in developing migration models, which will help to locate where at sea post-smolts are most likely to be found. It is recommended that consideration be given to a three-year survey period so as to optimise the results from this very costly and logistically challenging initiative. However, in advance of the preparatory meetings and full planning of the programme, it is only feasible to provide a summary and costing for the first year of the programme.

Objectives

- Determine the ocean migration patterns of salmon from fresh water to return to home waters;
- Provide adequate samples to describe the major migration routes and distribution of Atlantic salmon at sea;
- Provide samples for regional stock identification using the genetic baseline studies;
- Collect information on sea surface temperature, salinity, current speed, direction and other oceanographic and hydrographic information;
- Collect information on the predators and prey of salmon;
- Determine the distribution of salmon in relation to:
  - Sea temperature and currents;
  - Presence of prey;
  - Presence of predators;
  - Presence of competitors;
  - Ocean up-welling and productivity;
- Collect and analyse oceanic data (physical, chemical, biological) compared to the relative abundance of salmon (adults and post-smolts) captured in targeted trawl or sampling surveys;

- Collect information (scales, growth information, sex ratios, etc.) for studies on the energetics of oceanic migration;
- Integrate the ***SALSEA*** programme with major marine studies being undertaken by bodies such as ICES, NOAA and Fisheries and Oceans, Canada.

Methodology

Individual surveys will be conducted and data collected as outlined in the detailed SOPs. The coordination and logistics of the surveys will be under the direction of the ***SALSEA*** manager. Detailed annual post-survey meetings will be held to review results from each survey and to refine and agree on objectives and methodologies of future programmes.

Table 1: Suggested provisional outline of research cruise requirements per year

Cruise Origin	No. of Cruises	Days	From	To
Canada	4	20	Gulf of St Lawrence	Labrador Sea
United States	2	20	Gulf of Maine	Northern Nova Scotia
North American Total	**6**	**120**		
Eng/Wales	1	14	SW Irish Sea	Northwest England
Ireland/NI	1	14	NW Irish Sea	Western Norwegian Sea
Scotland	1	14	S E Scotland	Western Norwegian Sea
Norway	1	14	Southwest Norway	Mid-Western Norwegian Sea
	1	14	Greenland Sea	Western Barents Sea
Russian Federation	1	14	White Sea	Eastern Barents Sea
Iceland	1	14	South	South West Iceland
	1	14	North	North East Iceland
Faroes	1	14	Faroes	North Faroes
European Total	**9**	**126**		
Grand Total	**15**	**246**		

Timescale

Surveys in April-November 2007 with possibility of May-October 2008 and 2009. All major tagging studies should be planned to coincide with these sampling periods.

Work Package 3 – Task 4

Distribution and migration – analyse and collate data from the marine surveys, report on the distribution of salmon at sea, report on the biological and physical oceanographic factors which influence migration and distribution of Atlantic salmon and report on natural and man-made mortality factors which may significantly affect survival of salmon at sea

Justification

The open-ocean surveys will provide a wealth of data relating to post-smolt distribution at discrete intervals of time and space. The genetic analysis has the potential to provide the first comprehensive overview of discrete stock distribution in the marine environment and the synchronous recovery of tagged fish, particularly those carrying DSTs, will provide fine-scale data on individual fish movements. The ancillary physical, chemical and biological data collected during the survey will provide a comprehensive picture of the varying environmental parameters encountered by the post-smolts during the marine phase of their migration and may provide clues as to how these factors influence marine survival. Considering the immense datasets these surveys will generate it is essential that the analysis and interpretation of these results is closely coordinated in the context of clear deliverables and strict adherence to agreed timelines.

Objectives

It is certain that ***SALSEA*** will generate an enormous bank of novel and complex data which will take several years to analyse and interpret. At a minimum, the following factors should be evaluated within Task 4:

Genetic assessment of stock composition

- Evaluate the stock composition of the samples at differing geographic scales and assess deviations from expected proportions.

Man-made effects

- Evaluate ICES SGBYSAL report in relation to new data collected during trawl surveys;
- Evaluate the effects of directed fishing mortality;
- Assess the level of ocean contaminants in areas where post-smolts are located.

Predators

- Provide an assessment of predation from historical data and records;
- Compare the distribution of salmon and their predators.

Productivity

- Assess the effect of varying ocean productivity on survival of salmon;
- Combine existing time series of survival and growth of salmon with productivity studies, plankton surveys, weather satellite surveys, etc.

Food availability

- Examine whether the survival of salmon is dependent on the distribution and relative abundance of prey types (fish, crustaceans, squid);

- Investigate the distribution and abundance of prey types in relation to salmon survival.

Growth effects
- Investigate the relationship between survival and growth rate with new data and samples from the research surveys (Work Package 2).

Water temperature
- Investigate the relationship between survival and water temperature from existing long time-series and new data on SST, fixed stations and transects, DST data from the research surveys (Work Package 2).

Competition
- Examine the relationship between survival and competition with other pelagic fish species (herring, mackerel, blue whiting, lumpfish) taking into consideration: competition for food, competition for space, schooling effects.

Combined synergistic effects
- Consider overall natural mortality as a result of combined synergistic effects.

Research on the above should provide a clearer picture of the relative scale of natural and anthropogenic impacts on marine survival. Where possible or practical, it will facilitate the development of management advice on strategies to mitigate such effects.

Methodology

The ***SALSEA*** manager will assemble an expert group of scientists, representing a wide range of disciplines. This group will analyse the survey data and provide an interpretation of the results. If a three-year programme is agreed, the expert group should meet for up to 5 days in each year of sampling, to consider the data available, carry out subsequent analyses and generate an annual report which will form part of the main ***SALSEA*** report. The expert group will consider the previous topic areas to address mortality at sea.

The expert group should address migration routes and distribution of salmon at sea and should attempt to:

- Identify the migration routes of salmon originating from rivers in the North Atlantic area;
- Consider initial bioenergetic requirements of juvenile salmon for marine survival;
- Assess how accurately reared smolts mimic the migration patterns and distribution of wild smolts in the marine environment;
- Assess what determines migration and distribution in the early stages of migration;
- Investigate the influence of currents as a distribution vector in relation to active and passive migration;
- Investigate the influence of temperature, salinity, different water masses, light (day length) and ocean productivity (upwelling) as distribution vectors;
- Establish the distribution and relative abundance of prey types (fish, crustaceans and squid) and the distribution (horizontal/vertical) of salmon at sea in relation to prevailing environmental conditions;

- Re-evaluate the hypothetical distribution and migration patterns generated from theoretical models in Work Package 3 – Task1.

Timescales

Results from the marine sampling programme and initial recovery of tagged fish in home waters as grilse in the following year and multi-sea-winter salmon in subsequent years will require an analysis period of at least three years. The expert group should meet in each of these years with the aim of producing an annual report after each sampling year and a final detailed report will be produced at the end of the ***SALSEA*** survey period (January 2008, 2009 and 2010) – see Work Package 4.

Participating Countries

Representatives from each country who were involved in the marine survey programmes.

Potential Products

- Up to three annual Progress Reports;
- A comprehensive final ***SALSEA*** Report.

Work Package 4 – Communications

Introduction

The wild Atlantic salmon has many aspects to its value. In addition to those associated with its exploitation by fishermen, there are those associated with the salmon itself, a highly prized species and an indicator of environmental quality. People in general value the Atlantic salmon and are willing to support its conservation even if they have no interest in fishing for it. There is, therefore, likely to be much public interest in the ***SALSEA*** programme, ranging from conservation groups determined to restore salmon to its former abundance on local rivers to the millions of city dwellers who would relish the prospect of the 'King of Fish' returning in greater numbers to the rivers of Europe and North America. This should be of benefit in seeking funds from the private sector to support the programme. There will be a need to ensure that the vision of ***SALSEA*** and its findings are effectively and efficiently communicated in order to foster support for the programme and subsequent research.

One of the main aims of the ***SALSEA*** programme will be to enhance coordination of existing ongoing research, particularly in fresh water and the inshore zone. There is a need to ensure that mechanisms exist for effective communication between all scientists working on research on mortality of salmon at sea. Some proposals for enhanced coordination of research are included in the different Work Packages (e.g. proposals for workshops and reporting). The findings of the ***SALSEA*** programme will also be of great relevance to researchers working on the same problems in the North Pacific Ocean and the Baltic Sea, and there will be benefits from communication with scientists working in these areas.

The increased levels of marine mortality of Atlantic salmon in recent years is seen as a major impediment to restoration of those stocks which are below conservation limits, and also a threat to stocks which are currently regarded as healthy. Much has been achieved to improve habitat in fresh water and the focus is now on factors limiting survival at sea and the opportunities to counteract these. It will be vital that the findings from ***SALSEA*** are effectively communicated to managers so that appropriate actions can be taken to address those factors amenable to intervention.

This Work Package is designed to ensure that information about this ambitious research programme is effectively transmitted to the scientific community, fishery managers and the general public in a comprehensive and readily comprehensible manner.

Work Package 4 – Task 1

Promoting SALSEA to potential funders

Justification

NASCO's International Atlantic Salmon Research Board (IASRB) has taken steps to better coordinate the already significant ongoing research efforts funded by NASCO's Parties. These Parties, together with their partners, already invest in the region of £4.6 million annually in order to improve understanding of the salmon's marine phase and additional funds have been made available to the Board. However, the ***SALSEA*** programme will require substantial additional funds if the causes of marine mortality of salmon are to be properly understood. A major fund-raising initiative will be required, targeted at private companies and individuals who would like to be identified with the conservation and restoration of wild salmon stocks.

Objectives

To increase awareness of the proposed research among potential private-sector sponsors with a view to raising the substantial sums required to undertake the comprehensive and ambitious research programme.

Methodology

Fund-raising is a specialised field and professional advice on developing an appropriate strategy to promote ***SALSEA*** will be required. The Board has agreed to allocate funds for advice on this matter. There are a number of categories of potential donors who could be approached:

- NASCO governments, regional governments and public agencies in each country;
- Inter-governmental and international agencies e.g. EU, NATO, Nordic Council, IMO, OSPAR;
- The private sector (small and large companies e.g. pulp mills, international oil companies);
- Local groups and associations and NGOs;
- Wealthy individuals;
- General public (this also generates political support);
- Charitable Foundations;
- The salmon fishing tackle trade;
- Adventure tourism and outfitting companies;
- The tourism industry.

There is a range of different reasons which could be used to encourage potential donors to contribute funds:

- The salmon as an indicator of the quality of the aquatic environment;
- Unravelling the mysteries of its migrations and the fascination of its life cycle;
- Assisting the donor organization to demonstrate that its specific activities are not damaging the wild stocks;
- Giving a green image to those companies that may have been linked to environmental damage;
- Helping local fishing groups to discover what is happening to their salmon;
- Improving the negotiating position of governments and inter-government agencies;
- Peer pressure on governments to contribute directly to the programme;
- Love of the resource and the desire to have it available to future generations;
- Need to have a gene bank for the fish farming industry;
- Saving money by improving coordination of research;
- Filming the progress in real time of research cruises;
- Sponsoring a salmon;
- Obligations under legislation;

- Association of products (e.g. clothing) with environmental causes;
- Socio-economic aspects;
- Genetic mapping.

Timescale

Ongoing, following adoption of the ***SALSEA*** programme by the Board and consultations with a professional public relations adviser to develop a fund-raising strategy. The fund-raising strategy will need to have raised substantial sums of money before Work Package 3 can be undertaken.

Work Package 4 – Task 2

SALSEA on-line – Development of a SALSEA website

Justification

SALSEA will involve world-class scientists with specialist skills in all aspects of salmon research, supported by a wide network of colleagues and collaborators. The IASRB has established a website which provides background to the work of the Board and hosts the inventory of marine research. Further expansion of this website to include ***SALSEA*** is important and a cost-effective way of improving public awareness of the programme. It would also provide a means for ***SALSEA*** participants to share knowledge through dissemination of information on research methods and approaches, improvements in technology and progress reports on research as it is undertaken.

Objectives

To ensure effective communication of the programme and its findings to scientists, managers, sponsors and the general public.

Methodology

Web pages devoted to ***SALSEA*** should be developed outlining the programme and summarising progress in the programme to date. Details of ongoing research on marine mortality of salmon should continue to be included through the annual updates of the Board's inventory and the Board's Scientific Advisory Group (SAG) should continue to review opportunities for enhanced coordination of ongoing research. It will be vitally important that the ***SALSEA*** web pages include educational material for use by schoolchildren, fishermen and the general public who will be interested in this initiative to unravel the mysteries of the salmon's migrations and the opportunities to restore stocks. Innovative elements that might be considered could include real-time film clips of research cruises and information to help local fishing groups discover what is happening to their salmon.

The Board's existing inventory of ongoing research in relation to mortality of salmon at sea should be further developed, initially by the NASCO Secretariat, so as to ensure effective communication of findings to date.

The Board has agreed that results of projects which have been completed should be collated so as to provide a status report of current understanding of the causes of mortality of salmon at sea. Such a compilation should be made available on the website.

Timescale

Ongoing throughout the duration of the programme following its adoption by the Board.

Work Package 4 – Task 3

SALSEA Symposium

Justification

In 2002 a Workshop on Causes of Marine Mortality of Salmon in the North Pacific and North Atlantic Oceans and in the Baltic Sea was convened in order to improve understanding of the mechanisms resulting in the increased mortality of salmon at sea in the three areas, to identify research priorities and to stimulate enhanced cooperation and information exchange. There was strong agreement from those attending the workshop that it had facilitated a valuable exchange of information and that efforts should be made to continue the dialogue, to enhance coordination of work in the three areas and to improve cooperation in developing new technologies. There is substantial marine research on salmon now underway or planned in these three areas, of which the ***SALSEA*** programme would be a major initiative. The results of this research in the three areas would form the basis of a future expanded international symposium.

Objectives

Such a symposium would provide a forum for exchange of information derived from research programmes initiated both prior to and since 2002, and provide an opportunity for an exchange of information among scientists, identify research needs, and to communicate findings and ideas to salmon fishery managers and to the public. Information derived from the ***SALSEA*** programme should be a major contribution to this Symposium.

Methodology

The IASRB should organise a major international symposium in cooperation with the International Council for the Exploration of the Sea (ICES), the International Baltic Sea Fishery Commission (IBSFC) or the organization(s) responsible in future for management of salmon in the Baltic, the North Pacific Anadromous Fish Commission (NPAFC) and the North Pacific Marine Science Organization (PICES) when the results from the ***SALSEA*** programme, particularly the research cruises envisaged in Work Package 3, are available.

Timescale

2009 or 2010.

Work Package 4 – Task 4

Generation of the SALSEA Programme Report

Justification

SALSEA is designed to improve understanding of the factors affecting the mortality of salmon at sea and the opportunities to counteract these factors. ***SALSEA*** will bring together the best scientific expertise in the field of research on salmon at sea and it is envisaged that the findings will be published in high-quality peer reviewed journals. In addition, it will be vital to communicate findings from the research clearly and concisely to managers so that appropriate action can be taken, to funders of the research and to the general public.

Objective

The objective is to report the findings of this innovative programme of research to funders, scientists and managers.

Methodology

It is envisaged that existing reporting procedures established by the Board will continue for ongoing research programmes. However, marine research cruises (Work Package 3) and other major elements of the ***SALSEA*** programme will be the focus of a separate and detailed report synthesising the findings and making recommendations for management actions and future research priorities. A shorter, non-technical report might also be prepared for funders and the general public. Major fund-raisers might also wish to be involved in the work of the Board members so as to follow the progress of the research and to have an input to its planning and coordination.

Timescale

The report will be generated over a period of not more than three years following the large-scale marine survey, so as to allow ample time for data analysis and presentation.

Work Package 4 – Task 5

Administrative support for SALSEA

Justification

In the event that funding can be secured for the international research cruises, the Board may well need to consider employing administrative support to ensure a high level of communication, (both between ***SALSEA*** Parties and with the general public), project coordination, financial administration, and website development.

Objective

To ensure the efficient planning and coordination of the ***SALSEA*** programme and dissemination of findings.

Methodology

In addition to work carried out by the NASCO Secretariat, the Board may need to employ an assistant who should be technically qualified and have administrative skills. The key role will be to facilitate planning and coordination of Work Package 3 and dissemination of its findings.

Timescale

For the duration of Work Package 3.

Appendix 1

Supporting technologies, the further development of which would support the *SALSEA* programme

1. Novel Trawl Sampling Technologies

The development of new electronic survey techniques may add greatly to the suite of technologies available to researchers over the coming years. For example, the following techniques are currently under development:

- Large-area screening trawl;
- Open trawl digital observer/analyser;
- Open trawl pit-tag detector;
- Open trawl live sampler;
- Large-scale capture of migrating wild smolts.

Large-area screening trawl

This will be a specifically designed trawl for screening large oceanic areas for tagged reared salmon without catching or damaging salmon entering the trawl. It will be based on the current Salmon Trawl principle but with major modifications. As a prerequisite, it should be possible to haul at speeds up to 8 knots and have a large width allowing large areas to be screened per time unit. One of the major challenges will be to standardise each component of the trawl.

Open-trawl digital observer/analyser

This system will consist of a digital camera system placed in front of the trawl end, to film all fish passing through the open trawl. This will provide an opportunity to assess and observe additional fish, which are not captured in the trawl, thereby significantly increasing the information on the distribution of salmon. The pictures will be transferred to the boat via cable and processed onboard the vessel, providing an estimate of numbers of fish in the sampled area and a length distribution of these fish. The data can be related to hydrographic/biological data collected in parallel and used to describe the relationship between salmon distribution and the other parameters collected. A major challenge will be to differentiate between salmon and other fish in areas of abundant by-catch.

Open-trawl pit-tag detector

The open-trawl pit-tag detector will be a system for continuous detection of pit-tags passing the open trawl end. The system is currently under development at the IMR, Bergen, and has been tested. The current system needs significant modifications to be used in salmon research. A major challenge is to adjust the current system to the needs of this programme and to make it robust enough to be used over long durations in rough sea conditions.

Open-trawl live sampler

The open-trawl live sampler will be connected to the camera system to catch fish selectively passing the open trawl end. The fish will be stored in a live fish tank that will be retrieved when the haul ends. The major challenge is to construct the catching mechanism and to again make it a durable and robust system.

2. Data Storage Tags

Data storage tags, more commonly referred to as DSTs, Archival Tags, or data loggers, have been used in the open ocean and coastal zones since the early 1980s to successfully study the behaviour, physiology, life-history, migration patterns, and environmental preferences of numerous species. These tags complement the GSI approach outlined in the main body of the document and a combination of GSI/IA and DST tagging is needed to form a complete picture of salmon distribution and migration. The term "data storage" refers to the tag's ability to collect a time series of data whilst attached to an animal and store that time series in a non-volatile memory until the tag is collected and downloaded for analysis by the scientist. The actual data series that is collected by an individual tag can vary depending on the sensors fitted, which reflect the specific question asked in a study. Typical sensors can include pressure (used to infer depth), body temperature and ambient water temperature sensors, conductivity (used to infer salinity), and blue-green light sensors (used to estimate primary productivity and geolocation). Recent advances have added the ability in some devices to detect GPS positions transmitted from surface vessels.

The value of a DST-based study is that it allows a researcher to capture particular parameters during the entire time that an animal is at liberty, not just parameters that are available at the time of capture. For example, a trawl survey of salmon combined with genetic stock identification or perhaps PIT tag marking allows the researcher to know when and where a particular animal from a particular region or river has been captured in the ocean, i.e. distribution. The DST's ability to capture migration and environmental/physiological information in real time and store it in memory can be used to plot the migration path taken by an animal to its point of capture. In addition, the tag logs the ambient oceanographic conditions experienced along the migration path. For example, the depth and temperature information stored by a DST can reveal much about temperature, water mass preferences, or diving behaviour of each individual fish. The migration paths may also indicate when and where animals are exposed to potential mortality due to by-catch or predation.

The migration patterns of other pelagic animals (Itoh *et al.*, 2003) and even sea birds (Phillips *et al.* 2004) have been successfully determined by using DSTs. Since salmon do not swim with their backs out of the water while at sea, satellite tracking cannot be used to determine migration paths. When satellite tracking is not available, alternative methods of estimating an animal's position must be used and indeed are supported by most commonly available DSTs. Even though salmon do not typically swim on the surface, they do spend a lot of time near the surface, particularly at night. Temperature measurements made while the salmon is near the surface can be correlated with global sea surface temperature (SST) maps compiled from remote satellite infra-red imagery (AVHRR - Pathfinder, SEAWIFFS, etc.) to give a rough estimate of location. This technique is possible due to the fact that the ocean is predominantly thermally stratified on a latitudinal basis. Tags that measure sunlight levels can record the position of the fish with an accuracy of 1 degree of longitude and 3 degrees of latitude (Itoh, 2003). For even greater positional accuracy, tags that detect GPS positions transmitted from ships' depth sounders are available (Gudbjornsson *et al.* 2004). Of course, this method relies on the presence of a ship to alert the DST of its position. While light-based geolocation is less accurate it does not depend on any man-made external inputs.

Tag requirements and tagging programme design

Migration and distribution patterns have been identified as the primary objective of the ***SALSEA*** initiative. DSTs can greatly assist in the acquisition of relevant data. New and smaller DSTs suitable for tagging large reared salmon smolts are currently available but research is continuing with a view to developing lightweight tags suitable for use on smaller wild smolts. Although the cost of individual tags is high, each recaptured DST provides a wide range of very accurate data.

Prior to initialising any tagging project it is essential to take the following into account:

- Consideration of achieving as high a percentage tag recapture rate as possible is essential to a successful study (Reddin *et al*. 2004). Selecting animals from a well-controlled river, in combination with publicity campaigns, can increase recapture significantly. Also, radio or acoustic transmitters can be added to the animal through either double tagging or through integration. This will alert scientists of a tagged animal returning to a river system;
- The ability of the fish to carry the ideal DST should be determined;
- Evaluate the size range of fish to be used in the tagging experiment.

Recent studies have shown that larger reared post-smolts can carry an internal tag, such as a DST, and that recovery is possible. DSTs are often used as part of a comparative study where the bulk of the fish are tagged in a conventional manner.

Available technologies capable of providing geological position of tagged salmon can be categorised as follows:

- Depth and temperature tags - for temperature, depth and location (via SST), the smallest tag;
- GPS tags - for temperature, depth and acoustic listening from locations from vessels;
- Geolocation tags - for temperature, depth and location via light;
- Salinity tag - for temperature, depth, salinity and location (via salinity).

A related issue to justifying the expenditure for a large tag release programme is the likelihood of recapturing tags. The practice of recreational catch and release fisheries is increasing throughout the world and in many cases is mandatory in certain areas or is compulsory after a defined bag limit has been reached. Efforts should be made not only to improve tag detection and reporting but also to encourage national agencies to take into account the value of retaining tagged salmon when compiling management or by-catch regulations for both recreational and commercial fisheries.

Future development of DSTs

Utilizing advanced electronics to study salmon migration, distribution, and behaviour requires that compromises be made in tag features to assure the best match of technology to the study. The current target is to design a lightweight tag for wild salmon smolts, in the range of 40 to 50 grams. Scientists should specify the size and weight range of tags required and also the features required (e.g. temperature, depth, salinity, position, memory size, lifetime, etc.). Once manufactured, tests of sample dummy tags should also be carried out under controlled laboratory conditions.

3. Coded Wire Tagging

Background and introduction

At least ten countries are currently using coded wire tags in Atlantic salmon for release to the wild. In addition to recoveries being made in home waters during and after return from the high seas, valuable information has been gathered from recaptures in high-seas fisheries and in recent years from research vessel projects examining the early marine life and migration routes of post-smolts.

Existing CWT tagging and tag recovery programmes

Coded wire tagging of Atlantic salmon has been conducted in at least 17 countries in recent years, with about ten countries presently involved in active programmes. This tagging is being done for a variety of reasons, including assessment of stock enhancement and ranching programmes, assessment of marine survival, study of coastal migration routes and parasite loads in early marine life, and assessment of commercial fisheries. All agencies releasing CWT Atlantic salmon are requested to report their activities to the ICES Working Group on North Atlantic Salmon, including numbers and location of releases, and codes used. This allows a useful picture of tagging effort to be built up, and facilitates reporting of international recaptures. A compilation of each year's tagging and marking activities is included in the following year's Working Group report. An overview of the numbers of CWT released by country over the past 15 years is shown in Table 2.

It is believed that the usage reported to ICES is under-estimated, in particular in the case of Spain and Germany, and that the true usage is currently of the order of 750,000 tags per year. The great majority of these fish are of hatchery origin, though limited numbers of wild fish have been tagged in recent years (e.g. 4% in 1999, from five countries).

Most CWT recoveries are made in commercial catches in home waters (e.g. Irish drift net fishery), angling fisheries (e.g. several hundred CWT fish per year in the Delphi, Erriff and Galway fisheries in Ireland), or at river traps or other population monitoring facilities (e.g. River Bush in Northern Ireland, River Taff in South Wales). However, significant recoveries have also been made at locations distant from the release site.

For many years, while the Greenland fishery was operating, there was an internationally coordinated catch sampling programme which included counting of adipose fin clipped fish and recovery of CWT. In 1988 for example, 22,327 fish were examined, of which 404 were fin-clipped; from these, 110 CWT were recovered, representing about 0.5% of the sampled catch (Russell *et al.*, 1989). The origins of the tagged fish were USA (58), Canada (23), Ireland (17), England and Wales (8), Iceland (3) and Scotland (1).

Recent research vessel programmes involving sampling of post-smolts using pelagic trawls to the north of the British Isles and in the Norwegian Sea have involved the recapture of CWT fish. For example, a catch of 167 fish in the Faroe-Shetland Channel in June 1996 contained 10 CWT fish - 6% of the catch (Shelton *et al.* 1997). These fish were all from Ireland. From a total of "more than 3,000" post-smolts sampled between 1990 and 2001 in the Norwegian

Sea by Holm *et al.* (2003), 44 CWT were recovered, representing of the order of 1.4% of the catch; they originated from Ireland, England Wales and Spain.

Potential for a Coordinated Tagging Effort

At present, it appears that of the order of 1.5% of salmon post-smolts to the North of the British Isles and in the Norwegian Sea are coded wire tagged. Recaptures in recent years have given a fascinating insight into the migratory routes being used, and growth rates in the early marine stages. Recaptures of groups of tagged fish from a single source hint at shoaling behaviour (Shelton *et al.*, 1997).

If there is to be a large-scale post-smolt sampling programme associated with ***SALSEA*** then there is clearly scope for coordinating any current and proposed CWT programmes to coincide with this effort, to the benefit of both. Clearly, having a greater proportion of fish tagged in the marine stocks as a whole will increase what will be learned about marine migration and increase the reliability of observations. Involvement of more regions in tagging programmes, for example Rhine countries, France and Scandinavia, will greatly enhance the value of the sampling programmes. Any organisation currently undertaking tagging, or considering tagging in the foreseeable future, should consider major releases in the years that the ***SALSEA*** or other marine sampling programmes are planned. Information from marine recaptures will provide fascinating information with respect to migration routes and speeds, feeding, growth, condition, parasite loads, tendency to shoal, and early marine survival. Particular value both to the ***SALSEA*** participants and to the releasing agencies could be obtained from stratified releases using sequential CWT.

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Canada	104,713	136,070	50,479	0	0	0	0	0	0	12,089	0	0	0	651
US	857,306	466,605	623,621	609,805	655,646	0	0	0	0	0	0	0	0	0
Belgium	0	0	0	0	0	0	877	15,672	16,961	0	0	0	0	0
Denmark	0	0	0	0	0	0	7,332	18,167	27,107	0	72,900	0	0	0
England + Wales	250,024	241,544	401,085	212,306	251,125	209,271	226,224	179,291	105,952	9,5344	104,676	55,809	57,056	66,079
Faroes	11,820	0	0	0	0	0	0	0	0	0	0	0	0	0
France	18,682	21,476	19,188	37,490	16,385	0	2,000	9,000	35,586	0	0	0	0	0
Germany	0	0	0	0	0	0	0	0	?	?	?	?	?	?
Iceland	407,660	302,895	352,953	314,147	294,467	342,931	212,444	120,568	150,569	127,203	129,678	141,224	142,277	244,243
Ireland	127,663	471,152	299,018	362,854	269,166	298,307	316,710	361,626	261,141	311,272	289,029	271,722	348,949	318,386
Isle of Man	0	0	0	0	0	0	0	0	0	0	0	0	0	?
Northern Ireland	29,875	36,320	23,382	16,335	10,121	40,535	36,888	12,043	37,053	22,363	35,970	33,671	28,035	20,033
Luxembourg							?	?	0	0	0	0	0	0
Norway	0	0	34,700	66,000	0	0	0	0	0	0	0	0	41,308	?
Scotland	41,390	45,752	38,129	25,452	25,029	20,308	18,876	33,929	20,410	30,929	19,903	13,501	17,045	12,513
Spain	0	38,864	0	0	115,100	127,000	35,500	26,100	45,331	52,580	83,225	?	18,150	10,676
Sweden(w.Coast)	0	0	0	0	0	0	0	0	0	46,673	0	0	0	0
Totals	**1,849,133**	**1,760,678**	**1,842,555**	**1,644,389**	**1,637,039**	**1,038,352**	**856,851**	**776,396**	**700,110**	**698,453**	**652,495**	**515,957**	**652,820**	**672,581**

Table 2. Use of coded wire tags on Atlantic salmon (excluding Baltic) reported to ICES, 1990 to date. Some of these figures are under-estimates. Where a question mark appears against a country it is believed that they have released tagged fish but this has not been reported to ICES.

4. Sonic Tags and Sonic Detector Arrays

Major advances have been made in sonic telemetry technology in recent years, and currently a number of tag models are available that can be implanted in individual fish, down to the size of wild smolts. Receiver technology has also improved, and become more affordable. Tags can be purchased that will transmit information beyond the simple identification of the fish. For example, models are available that provide data on temperature and depth, and manufacturers are working on additional capacity.

The advances in the technology makes sonic telemetry a powerful and relatively affordable tool to follow the movements of individual fish in salt water and the environmental conditions that they are moving through for extended periods (> 6 months – years).

Through the strategic positioning of receiver arrays either at geographic constrictions (e.g. fjord or estuary mouths; spaces between islands and the mainland) or if they exist, across relatively restricted migratory pathways of salmon (e.g. narrow continental shelves), it is possible to obtain quantitative estimates of the number of salmon surviving to reach the site of the array. By strategic positioning of arrays, it may be feasible to identify mortality "hot spots" for salmon in the ocean, and correlate the losses to probable causes.

For Atlantic salmon in North America, estimates have been obtained of the percentages of tagged smolts successfully transiting fresh water and/or the estuaries of the Narraguagus, Dennys, Ste. Croix, Magaguadavic, Big Salmon, Saint John, Miramichi and Restigouche Rivers. In addition, limited but successful work has also been accomplished on quantitatively tracking salmonids to coastal waypoints on both the East (Bay of Fundy) and West (Pacific Ocean Salmon Tracking project) Coasts. These studies have documented striking regional differences in the early mortality of smolts, suggesting that the factors contributing to the present high mortalities observed for Atlantic salmon differ among regions.

Appendix 2

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Appendix 3

COSTINGS

Listed below are indicative costings for both *Work Package 1 – Supporting Technologies* and *Work Package 3 – Oceanic Distribution and Migration*. These are the priority areas for fundraising and the success of the fundraising initiative will dictate the extent of administrative support required and the scale of the communications programme. It should be noted that administrative costs related to Work Package 4 are likely to be substantial and could reach £500,000 over a five-year period. No costings are provided for *Work Package 2 – Early Migration* as it is assumed that this work will continue to be carried out by the Parties, but will include a greater level of cooperation and coordination of research in the priority areas previously outlined in this report.

Work Package 1 – Supporting Technologies

Work Package 1 Task I

Genetic tagging to determine stock origin **£1.5million**

Work Package 1 Task 2

Sampling equipment evolution **£330,000**

Work Package 1 Task 3

Signals from Scales **£100,000**

Sub-Total £ 1.93 million

Work Package 3 – Oceanic Distribution and Migration

Work Package 3 Task 1

Distribution and Migration Mechanisms **£25,000**

Work Package 3 Task 2

A Common Approach **£25,000**

Work Package 3 Task 3

Salmon at Sea - two years of marine surveys (see detailed yearly costings below) **£5.6 million**

Work Package 3 Task 4

Distribution and Migration **£180,000**

Sub-Total £5.83 million

Total: £7.76 million

Suggested provisional outline of research cruise requirements and costs per year

Cruise Origin	No. of Cruises	Days	From	To	Estimated Cost (million £)
Canada	4	20	Gulf of St Lawrence	Labrador Sea	1.05
United States	2	20	Gulf of Maine	Northern Nova Scotia	0.46
North American Total	**6**	**120**			**1.51**
Eng/Wales	1	14	SW Irish Sea	Northwest England	0.12
Ireland/NI	1	14	NW Irish Sea	Western Norwegian Sea	0.12
Scotland	1	14	S E Scotland	Western Norwegian Sea	0.25
Norway	1	14	Southwest Norway	Mid-Western Norwegian Sea	0.20
	1	14	Greenland Sea	Western Barents Sea	0.12
Russian Federation	1	14	White Sea	Eastern Barents Sea	0.12
Iceland	1	14	South	South West Iceland	0.12
	1	14	North	North East Iceland	0.12
Faroes	1	14	Faroes	North Faroes	0.12
European Total	**9**	**126**			**1.29**
Grand Total	**15**	**246**			**2.8***

**Note: Estimated costs are at national rates and could vary considerably depending on various economic factors plus origin of research vessel (Agency-owned versus contracted commercial vessel). The costs are per year. Therefore a programme involving research cruises according to the outline above in two or three consecutive years would cost in the region of £5.6 million and £8.4 million respectively.*