

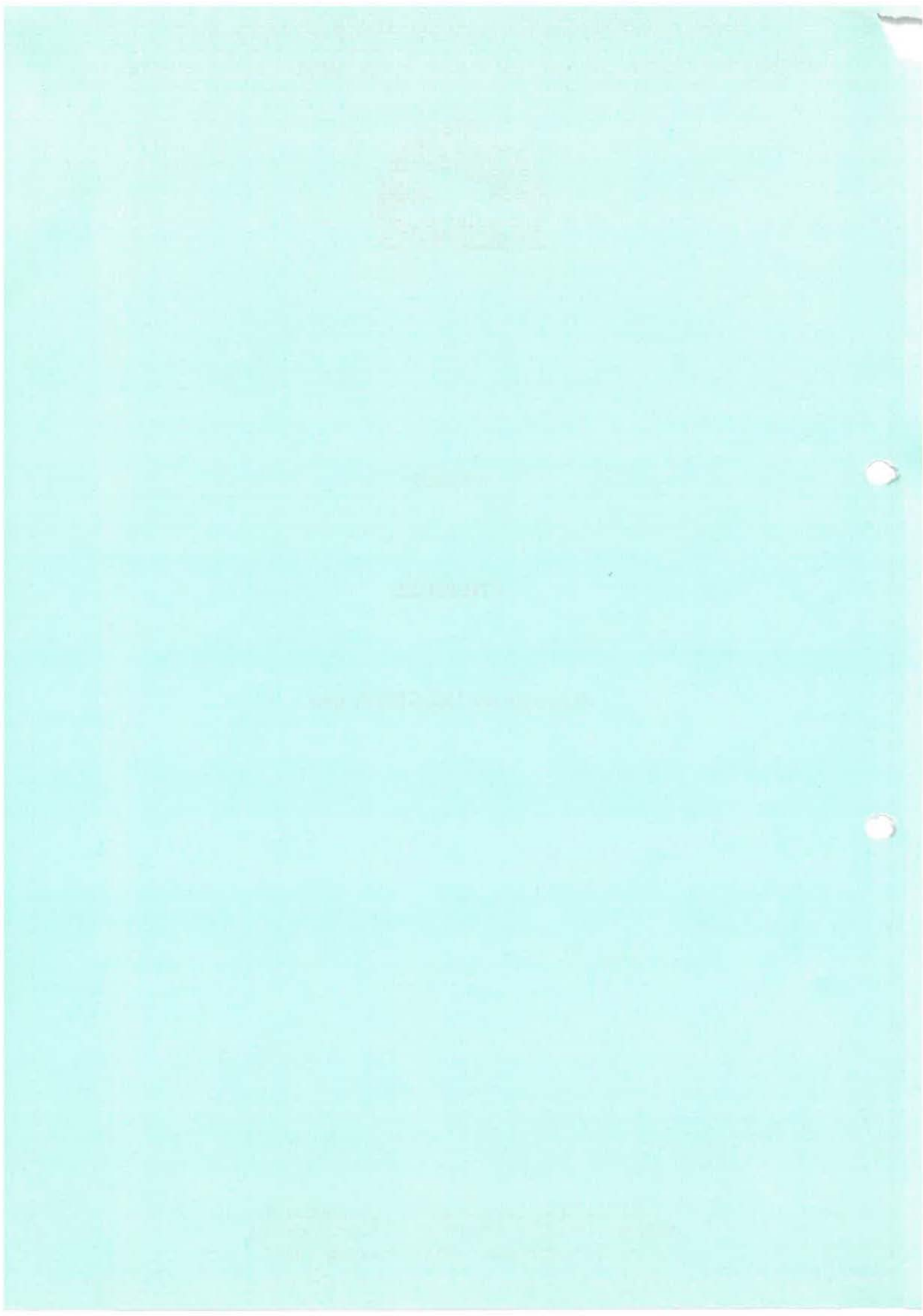


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Report on the SALGEN Project



Review of Genetic Studies on Atlantic Salmon to Increase Understanding and Improve the Effectiveness of Wild Stock Conservation and Rebuilding Programmes in Europe (SALGEN)

An Interim Report: 30 April 2003

An EU Accompanying Measure



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The Atlantic Salmon Trust
Moulin, Pitlochry
Scotland PH16 5JQ
UK

Chairman, Project Steering Committee
Dr. E. Verspoor
Freshwater Programme
Fisheries Research Services
Marine Laboratory
PO Box 101
Aberdeen, Scotland AB11 9DB
UK

Project Steering Committee

E. Verspoor (FRS Marine Laboratory, Scotland) (**Chairman**)
J. Webb (Atlantic Salmon Trust, UK)
C. Garcia de Leaniz (Centro Ictiologico de Arredondo, Spain)
P. McGinnity (Department of the Marine, Ireland)
L.P. Hansen (Norwegian Institute for Nature Research, Norway)
W.C. Jordan (Institute of Zoology, England)
M.-L. Koljonen (Finnish Game and Fisheries Research Institute, Finland)
A.F. Youngson (FRS Freshwater Laboratory, Scotland)

Scientific Steering Committee

E. Verspoor (FRS Marine Laboratory, Scotland) (**Chairman**)
H.B. Bentzen (Aquaforsk, Norway)
L. Bernatchez (Laval University, Canada)
T.F. Cross (University College Cork, Ireland)
K. Hindar (Norwegian Institute for Nature Research, Norway)
W.C. Jordan (Institute of Zoology, England)
T. King (US Geological Service, West Virginia)
M.-L. Koljonen (Finnish Game and Fisheries Research Institute, Finland)
E.E. Nielsen (Danish Institute for Fisheries Research, Denmark)
J.A. Sanchez (University of Oviedo, Spain)

BACKGROUND

Atlantic salmon stocks across the species' range are in decline, with many stocks extirpated or on the verge of extinction. In response, considerable effort has been directed over the past century at restoring stocks. However, success has been mixed at best and, to improve success, NASCO asked for the development of scientific guidelines for the deployment of stock rebuilding programmes.

Existing stock rebuilding programmes generally fail to take into account genetic population structuring and adaptive population differentiation. Most limit exploitation or produce fish for stocking, without regard to genetics. This is inappropriate given the survival, character and reproductive success of Atlantic salmon, and the viability of salmon stocks, are determined by the interaction of genes, at both the individual and population level, with the local environment.

Addressing genetic issues is not simple as the gene-environment relationship is extremely complex and poorly understood. What knowledge does exist is scattered, not easily accessed by managers, and a useful, consistent up-to-date source of scientific guidance on genetic issues is lacking.

Investigations into the genetics of the Atlantic salmon have increased over the past decade, many funded by the EU. These reinforce the view that the species is genetically variable at both the individual and population level. However, the full extent of this variation and its importance to survival, character and reproductive success remain to be fully assessed. This has given rise to differing views on genetic management in relation to issues such as exploitation, population reductions, stocking, escaped farm fish, habitat change and supportive breeding.

Many studies on Atlantic salmon carried out have been published, others remain to be published, and more are on-going. The results of these studies need to be reviewed and integrated to develop a

scientifically sound and collective perspective, which will maximally advance general knowledge and allow development of a consensus on the genetic management of stocks. This represents the most rapid and cost-effective way of improving scientific advice to resource managers. It will, in turn, lead to the development of improved Atlantic salmon stock conservation and rebuilding programmes, help to clarify research priorities and ensure effective targeting of future research.

AIM AND OBJECTIVES

In response to the need for an up-to-date consensus, view on Atlantic salmon genetics accessible to resource managers, the SALGEN project was submitted and funded by the European Commission in 2001, under the Accompanying Measures programme of Framework VI. Its stated overall aim was:

“...to improve understanding of population structuring and intraspecific biodiversity in EU Atlantic salmon stocks and deliver consensus, “state of the art” advice to resource managers for addressing genetic issues in stock conservation and rebuilding programmes”

To meet this aim, the specific objectives of the project were:

- *To undertake and prepare for publication a comprehensive written collation, synthesis and review of available data within and among Atlantic salmon stocks in relation to protein, mitochondrial DNA, nuclear DNA (including chromosomes) variation, and quantitative and experimental genetic studies*
- *To review issues important to stock conservation and rebuilding and develop and publish guidance on genetic issues for managers of salmon stocks, including population structuring and adaptation, genetic differentiation of farm and wild stocks, population discrimination using molecular markers, effects of population reductions, stocking, farm escapes and habitat change, supportive breeding programmes gene banking and stock re-establishment.*

SALGEN set out to achieve its aim and objectives by holding a series of four workshops and a symposium. The workshops were to be held to review the four main sources of information on the genetic character of Atlantic salmon stocks: proteins, mitochondrial DNA, nuclear DNA, and quantitative and experimental studies. The symposium would address the implications of the available genetic information on Atlantic salmon for management issues. Through the workshops and symposium, SALGEN would deliver:

- *a special supplement in the Journal of Fish Biology encompassing primary peer-reviewed papers describing previously unpublished work on genetic protein variation in the species*
- *four review papers to be submitted to the Journal of Fish Biology, one describing the work from each of the four workshops.*
- *peer-reviewed symposium proceedings published as a book providing a non-technical description of the genetics of the Atlantic salmon and its implications for species management in relation to the main conservation and stock rebuilding issues.*
- *a booklet to be published by the Atlantic Salmon Trust providing a summary statement of guidance on genetic issues for managers of Atlantic salmon stocks.*

PROJECT UPDATE

SALGEN commenced 1st October 2001 and will finish 30th September 2003. The first four months of the project focused on the organisation of the programme of meetings, the following twelve months on preparing for and holding these meetings, and the final eight months is focused on the completion of the deliverables.

The Challenge

The challenge undertaken by SALGEN is put in perspective when one considers that there are over 300 papers alone on protein variation in Atlantic salmon and at least a thousand more addressing other aspects of the species' genetics. Furthermore, these papers must be evaluated, collated and integrated in the context of the broader literature on fish and general genetics, to provide maximal insight into the Atlantic salmon genome and into what studies reveal about population structure and adaptive population differentiation.

The Atlantic salmon genome contains in the order of 30,000 to 100,000 genes, most of which can be expected to be variable and some variation can be expected to influence individual character, survival and reproductive success. Only a few genes have so far been studied and, even for these, knowledge is incomplete. Studies have also only encompassed a small portion of the over 2000 river systems Atlantic salmon inhabit, in Europe and North America. Yet this range spans thousands of kilometres from north to south, and east to west, covering a wide range of environmental conditions, from northern Spain and north-eastern USA to arctic Russia and Canada. The potential for genetic variation among stocks through homing, reproductive isolation and local adaptation is inescapable.

The scope for drawing inferences on the genetic character of the species from available data will often be severely constrained. It requires careful consideration of the scattered and varied insights derived from individual studies with each researcher bringing a few, unique pieces of insight into the species genetics, and their own views on the overall picture. To develop a consensus view on population structuring and adaptive population differentiation, and its management implications, for Atlantic salmon, involves bringing together more than 40 scientists from 15 different countries, exchanging information and seeking common ground. This represents a challenge, just from a logistic perspective.

Meetings

Researcher groups and individuals working on the different classes of genetic variation in the Atlantic salmon were invited to apply to participate in the four SALGEN data review workshops. Workshop Steering Groups (WSG) were established through the Scientific Steering Committee, appropriate applicants selected and invited, an external expert identified by each WSG to monitor and critique the workshop proceedings and output. The participants of the workshops were then invited to contribute to the management issues based SALGEN symposium. A summary of each of the meetings is provided below.

Mitochondrial DNA Workshop – Genetic data on Atlantic salmon, derived from the analysis of mitochondrial DNA, was considered at a meeting convened on **26-27 April 2002** at the **Institute of Zoology, London**, England. The workshop was hosted by Dr. W.C. Jordan and organised by Dr. E. Verspoor. Dr. J. L. Nielsen of the Alaska Department of Fish and Game, an internationally recognised expert on the molecular genetics of

Onchorynchus spp. participated as the external expert. Twelve researchers, representing the main research groups working in this area, presented papers on their studies on mitochondrial DNA and the collective implications of their studies were considered. A broad consensus was reached and an agreement was obtained on the development and structure of a multi-authored review paper. Dr. R. Gross, Estonia agreed to take the lead in its production. A draft of the review, representing a collation and synthesis of available information has now been produced and is being circulated for comment.

Nuclear DNA Workshop – Genetic data on the Atlantic salmon derived from the analysis of nuclear DNA, including chromosomes, was considered on **29 April- 2 May 2002** at the **Institute of Zoology, London**, England. The workshop was hosted and organised by Dr. W.C. Jordan. Dr. M. Beaumont, University of Reading, UK a leading researcher on methods for the analysis of nuclear DNA data attended as external expert. The meeting included 22 presentations by researchers covering the full range of nuclear DNA studies of Atlantic salmon and its application to management. The implications of the data were discussed and agreement was reached on a framework for a multi-authored review of the subject area, with Dr. Jordan taking the lead. The contributors to the paper have been identified and their contributions are currently being integrated and assembled into a draft manuscript for collective consideration.

Protein Workshop – Work carried out on genetic protein variation in the Atlantic salmon was reviewed on **12-15 June 2002** at the **Marine Laboratory, Aberdeen**, Scotland. The workshop was hosted and organised by Dr. E. Verspoor. Professor J.A. Beardmore, Swansea University, a international authority on fish genetics and protein polymorphisms participated as the external expert. Sixteen researchers made presentation reviewing published and unpublished studies. The implications of the work discussed and agreement was reached on the content and structure of the multi-authored review paper describing the results of the workshop. Dr. Verspoor will take the lead and a draft of the review is currently in preparation. Fourteen manuscripts, describing previously unpublished work, have been submitted for publication in a special supplement of the *Journal of Fish Biology* on genetic protein variation in Atlantic salmon.

Quantitative and Experimental Workshop – Experimental studies of quantitative genetic variation in the Atlantic salmon were reviewed at a workshop on **13-15 September 2002** at the **Centro Ictiologico de Arredondo, Arredondo**, Spain. The workshop was hosted and organised by Dr. Carlos Garcia de Leaniz. Professor T.P. Quinn, University of Washington School of Aquatic & Fishery Sciences, one of the worlds leading researchers in the field of *Onchorynchus* spp. biology, participated as the external expert. Papers were presented by 22 participants and the implications of the work for our understanding of salmon genetics and salmon management discussed. The meeting reached agreement on the development and structure of a multi-authored review paper, with Dr. Garcia de Leaniz taking the lead. Writing of the review components is now underway and a draft manuscript is in the process of being assembled.

Symposium on the Genetics and the Conservation of Atlantic Salmon – Following the workshops, a symposium was convened from **12-14 January 2003** at the **Hotel Westport** in Westport, Ireland. It brought together researchers and experts from the SALGEN workshops. with managers and biologists concerned with Atlantic salmon conservation and stock rebuilding programmes. The meeting encompassed 15 multi-authored presentations by researchers and six mini-workshops for discussion of management among researchers,

biologists and resource managers. Part I of the meeting served as an introduction and included five talks on the following topics:

- *the importance of genetics in conservation management*
- *the basic genetic character of the Atlantic salmon,*
- *the study of the genetics of populations,*
- *the practical use of genetics in management*

Part II of the meeting covered current understanding of the genetics of Atlantic salmon and was composed of five presentations on:

- *population structuring*
- *demographic variation*
- *population adaptation*
- *the genetics of cultured stocks*
- *population identification*

Part III of the meeting encompassed six talks on specific areas of management concern. Covered were:

- *population reductions,*
- *fisheries exploitation*
- *habitat change*
- *stocking and ranching*
- *farm escapes*
- *gene banking and supportive breeding programmes*

Each talk in Part III was followed by a mini-workshop for fuller discussion of the implications of existing knowledge on species genetics for the management issues, and how this information can be applied to improve management practise.

Overview Of Progress

SALGEN has successfully brought together most of the leading scientists researching Atlantic salmon to review available genetic data on the species. The workshops proved a highly productive environment for the presentation of information and discussion of the implications of the results for our understanding of the genetics of the species. Feedback from researchers highlighted the value of the meetings for up-dating individual knowledge, exchanging ideas, and developing a consensus on the current state of knowledge and its implications for Atlantic salmon management. New research collaborations have been developed in a number of cases and many stimulated to prepare primary papers describing unpublished studies.

Immediate benefits from the SALGEN symposium were realised in the form of the specific opportunity it provided for the focused interaction of salmon geneticists with resource managers and biologists on the science related to the genetic management of Atlantic salmon stocks, independent of political issues. More importantly, however, the symposium highlighted to researchers the nature of the challenge they face in communicating current understanding of Atlantic salmon genetics, and its implications for management, in a form accessible to and understandable by resource managers and biologists, as most lack a specialist genetics background. The feedback obtained has had a major impact on the development of the book reporting the symposium presentations, and will help to ensure clarity in the presentation of the guidance generated.

The symposium presentations are currently being revised in the light of feedback and form the basis for the chapters of a book on the genetic management of Atlantic salmon to be published by Blackwell Science Ltd. The book will provide an up-to-date reference on genetics management of Atlantic salmon for managers and biologists. Revised draft chapters will be further reviewed and their written presentation co-ordinated at an authors meeting to be held at the Institute of Zoology, London, 30-31 May 2003.

The book will build on the material presented and reviewed in the review papers arising from the data review workshop. Initial timeframes for completion of these papers have been extended to deal with the volume of information, heavy work commitments of participants, and the unexpected time demands associated with co-ordinating input from multiple authors. This has also proved the case with regard to the writing of the book chapters such that a request was made to the EC to extend the time frame for the project to the originally requested 24 months, from the 18 months granted. Current plans see the journal supplement, review papers and book submitted for publication by 30 September. Taking into account publishing delays, the deliverables are expected to be in the public domain early in 2004.

Preliminary Findings

The process of developing a detailed consensus statement on guidance in relation to genetic issues in relation to stock conservation and rebuilding programmes is still underway. Guidance on specific topics is still in the process of being developed and refined but a wide consensus was apparent with regard to the following:

- *Specific knowledge of the genetic nature of the Atlantic salmon is limited and current understanding of the genetic nature of the species is based on inferences drawn from analyses of a very small portion of the species' genome in a small number of stocks.*
- *Atlantic salmon are highly structured into genetic populations, with most if not all river stocks belonging to different populations, and the stocks of most larger rivers being composed of multiple individual populations.*
- *The species appears less variable than most salmonids but still shows a high level of variation both within and among populations; with modern molecular and statistical technology components of this variation can be successfully exploited to establish the relatedness of individuals and their membership of populations*
- *Contemporary gene flow among populations occurs but is sufficiently constrained such that populations need to be managed as separate biological units.*
- *The species is divided into two major phylogenetic groups which show levels of differentiation which justify consideration for designation of stocks in Europe and North America as distinct subspecies.*
- *Within the two continental phylogenetic groups exist further phylogenetic divisions, indicating historically highly restricted gene flow between many regions, the main one so far identified being that between Baltic and Atlantic salmon stocks in Europe.*
- *Species populations are genetically adapted to the conditions of their local environments in ways which increase their survival and maximise reproductive success, determining the character and level of recruitment.*
- *Reductions in population numbers result in the loss of genetic variation a process historically countered by gene flow and mutation, and minimised by the demographic structuring of populations in relation to factors such as early maturing parr and over-*

lapping generations; genetic losses will impact the long-term adaptive capacity of a population.

- Deliberate or inadvertent mixing of native and non-native stocks, from stocking or escapes of farm fish, will in many cases have negative consequences for the character and abundance of native populations, through both their genetic and ecological interaction; this will include most numerically depressed populations with reduced genetic variation; insufficient knowledge exists to define under what circumstances mixing is or is not sustainable, but where it occurs it needs to be carefully managed and its consequences monitored and assessed, for outcomes to be positive.*
- Fisheries exploitation is by its very nature selective and will cause the genetic alteration of populations, with consequences for the character and abundance of different stock components in many rivers; this needs to be managed.*
- Habitat change brought about by human activities can result in an overall loss of genetic diversity in the species, where populations are extirpated or reduced in number, or in a loss in fitness due to a reduction in the adaptive value of the gene pools of affected populations in the new environmental circumstances.*
- Management tools such as hatcheries and supportive breeding can be used in conservation and stock rebuilding but genetic management is essential to avoid problems related to inbreeding and outbreeding depression.*
- The successful integration of genetics into Atlantic salmon management requires that resource managers and biologists work closely with geneticists to cost-effectively integrate genetic management concerns and tools into current management systems.*

CONCLUSION

SALGEN set out to complete a demanding set of objectives in relation to the development of an up-to-date, consensus review of available information on the genetics of Atlantic salmon and its implications for management issues in relation to stock rebuilding programmes. The task has proven a major challenge due to the volume of information, both published and unpublished, and the logistic challenge associated with assembling researchers from over 15 different countries to carry out the review. Despite a setback to the project timeframe, the milestones and deliverables will be produced as contracted. As intended, the synthesis of information, development of a consensus view, and its presentation of output a form accessible to resource managers and biologists is expected to provide a valuable resource to facilitate development of a more scientifically sound basis for genetic management of Atlantic salmon stock rebuilding programmes across the species' range.

For further information contact Eric Verspoor at e.verspoor@marlab.ac.uk, or visit the SALGEN website at <http://www.salgen.marlab.ac.uk>.