

THE INSTITUTE OF AQUACULTURE



**Annual Report
2001-2002**



**UNIVERSITY OF
STIRLING**

Contents

Highlights		3
Introduction		3
Teaching		4
Disease Group		4
Reproduction and Genetics Group		7
Nutrition Group		11
Environment Group		13
Systems Group		15
Stirling Aquaculture		18
External Facilities		19
Howietoun		19
Buckieburn		19
Machrihanish		19
Machrihanish Marine Farm Ltd		20
Appendix I	Advisory Committee	21
Appendix II	Staff List	22
Appendix III	Postgraduate students	23
Appendix IV	Theses	24
Appendix V	Publications	25

For information on the Institute of Aquaculture contact

tel: 01786 467870 fax 01786 472133
<http://www.stir.ac.uk>

Highlights

- Institute received a 5 rating in the UK Research Assessment Exercise
- University Development Fund award for three new lectureships
- Wellcome Trust Equipment Award received for the purchase of a confocal microscope
- Substantial university-funded improvements to the Buckeiburn Freshwater Unit
- Commercial marine fish hatchery commissioned at Machrihanish
- MSc Aquaculture and undergraduate students numbers were high. New MSc and MRes programmes have been developed
- Semi-automated recognition system developed for the notifiable pathogen, *Gyrodactylus salaris*
- New molecular diagnostic techniques developed for viral pathogens
- Research on welfare of farmed trout points up importance of water quality parameters
- A molecular-cytogenetic analysis of sex determination in tilapia will enable new initiatives in gender control in fish
- Studies have further demonstrated the possibilities for the replacement of fish oil with vegetable oil in commercial diets
- New programmes are assessing the impacts of pollutants in tropical freshwater systems
- The Institute is leading a DEFRA-funded consortium to measure the biological effects of pollutants on fish in UK estuaries
- A growing range of GIS-based planning tools have been developed for the aquaculture sector in the UK and overseas
- Successful year for salmon smolt sales from Howietoun although brown trout sales remain affected by the foot and mouth outbreak
- Stirling Aquaculture is providing management support for a new commercial marine farm in Libya
- Record number of staff publications

Introduction

The Institute has had a very successful year in 2001-2002 with the highlight being the award of a 5 rating in the UK Higher Education Funding Councils Research Assessment Exercise. This top rating, which underlines the international quality of the Institute's research, has led to a very substantial increase in research funding from SHEFC which has dramatically improved our financial position and enabled a consolidation of staff and infrastructure. It was particularly pleasing that virtually all our academic staff were included in the RAE and I would like to register my appreciation of their tremendous efforts. A 5 rating will be most important in attracting outside support for research. Funding for 3 new lectureships, aquarium refurbishment and associated technical support has been awarded from the University Research Development Fund. The new lectureships are particularly welcome in that they will allow us to take forward staff succession planning in some areas, an issue which needs to be addressed before senior staff reach retirement age.

The Institute continues to improve its infrastructure wherever possible, although much of the necessary funding has to be obtained from outside sources. Thus, SRIF-funded upgrading of analytical equipment is now complete and we were fortunate to be awarded very substantial funding from the Wellcome Trust for the purchase of a confocal microscope. This will open up a number of new areas of research throughout the Institute and it is particularly pleasing to receive funds from this prestigious source. The Buckieburn Freshwater Unit has been redeveloped with funding from the University. Tank buildings are now improved and much needed laboratory, office and staff facilities have been completed, creating a far better working environment.

There will shortly be fundamental reorganisation of the Faculty of Natural Sciences with a merger of the Departments of Biological and Environmental Science to form a new School. This may have some implications for the Institute, notably in respect of undergraduate teaching. Our financial return from undergraduates has decreased sharply in recent years. It is important that this trend is reversed, possibly by the Institute assuming management of aquatic teaching, or that the Institute's input to such teaching is rationalised.

I am pleased to report new developments in post-graduate teaching with the finalising of the MSc in Sustainable Development in conjunction with the Department of Environmental Science, and the development of an MRes in Aquatic Science. These courses add considerably to our portfolio of existing postgraduate courses and there may be scope for further developments in this area.

The Institute has already been extremely successful in generating commercial income from a range of activities and this year has been no exception. The most significant event has been the commissioning of the new marine fish hatchery at Machrihanish, a joint venture with Lakeland Smolt Ltd. This impressive facility will place us at the forefront of new technology and research opportunities in marine fish culture as well as providing substantial income.

Our 1997-2002 strategic plan has now concluded with almost all our objectives and targets achieved or exceeded. We now need to develop a plan for the next 5 years and to this end consultations have begun with staff on future strategies. We hope that a plan will be completed early next year to serve as a guide and framework for our activities over a period in which we need to build upon our recent successes.

R H Richards
Director

Teaching

Postgraduate

Only the MSc Aquaculture course was run in 2001-2002. Student numbers were much improved with a total of 25 participants, including 5 from non-EU countries. Congratulations are due to Adam Brooker, Patrick Reynolds and Maria Sefteli who were awarded distinctions. Maria was awarded both the Royal Highland and Agricultural Society of Scotland silver medal and the External Examiner's prize.

The Institute has sought to increase its portfolio of Masters courses and two new courses are planned to commence in autumn 2003. These are an MSc in Sustainable Development and an MRes in Aquatic Science. These courses will involve collaborations with the new School formed by the amalgamation of the departments of Environmental Science and Biological Science.

Thirteen new postgraduate research students started their studies in 2001-2002. This is a decrease on the unexpectedly high numbers joining in the previous year, but it is pleasing that eight of the 2001-2002 intake were from non-EU countries. Nineteen PhD students graduated in 2001-2002.

The Institute was again awarded two NERC CASE studentships on 2001-2002. Matthew Sprague will study with Professor Bromage and Dr C Talbot of Nutreco ARC, whilst Patrick Reynolds will be supervised by Drs Telfer and Jauncey, with CASE funding from Biomar Ltd.

Undergraduate teaching

In the 2001-2002 honours year there were a total of seven students, six of whom graduated with a 2(i) and the other with a 2(ii). The semester 8 projects undertaken by these students covered a very wide range in terms of both geographical location and project content. Projects included; the biology of the copepod parasite *Lernaecocera branchialis*; mariculture of the sea hare *Stylocheilus striatus* in Australia; a study of ferric chloride as a flocculant at Two Oceans Aquarium, Cape Town, South Africa; barramundi (*Lates calcarifer*) studies in Australia; *Artemia* cyst preparation; environmental impact assessment of long-line mussel culture in Loch Fyne; and respirometry of pez blanco (*Chirostoma estor estor*) in Mexico. Feedback from the project supervisors, the external examiner and the students themselves was very positive. During this year semester 3, 5 & 7 undergraduate units offered by the Institute of Aquaculture also ran. The semester 7 ½ unit system was once again very well received by the students.

Income from undergraduate teaching has declined in recent years and is likely to fall still further next year and thereafter. The issue will need to be addressed and income restored or undergraduate teaching effort rationalized.

Other teaching

The annual fish disease course was held in January with 32 participants, the largest number for some time, again underlining its value to industry. SCOTPIL courses for Home Office personal licences were run and a number of student groups from UK and European higher education establishments visited the Institute and Howietoun.

Disease Group

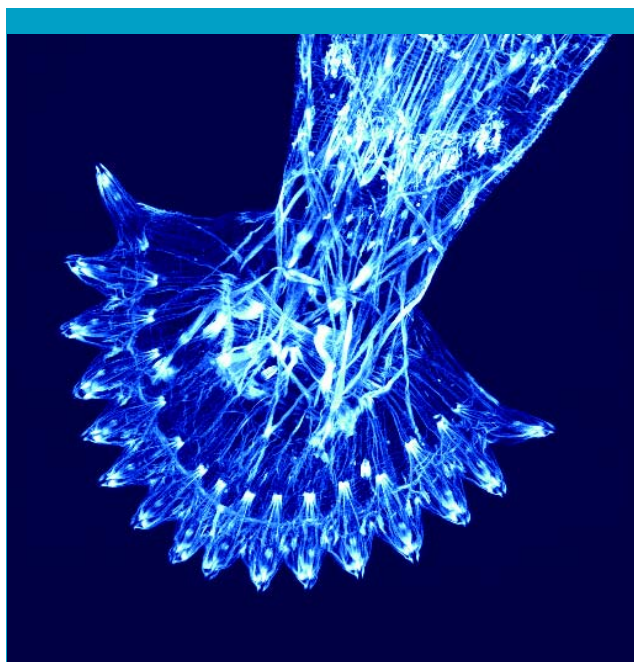
The Disease Group has had a productive year with continued increase in the use of molecular based technologies. These are now particularly important in vaccine development and this continues to be a major research area, with some potentially rewarding developments in the viral field.

Parasitology

The Parasitology Group has had another active year maintaining five full time research contracts and successfully completing 5 PhD programmes.

During 2001-2 Dr Andy Shinn has made considerable progress towards delivery to CEFAS of a semi-automated recognition system for *Gyrodactylus salaris*. Under a grant awarded to Professor Sommerville, Andy Shinn and Jim Kay of Glasgow University, this novel system is a statistical classifier based on morphometric data derived from an image processor, and will determine whether any given specimen of *Gyrodactylus* is *G. salaris* or not. In collaboration with scientists at CEFAS, the classifier is currently being installed and will be ready for field testing by Ministry diagnosticians early in 2003. Dr Shinn continues to collaborate on *Gyrodactylus* with colleagues from the Zoological Museum, University of Oslo, the University of Nottingham and the University of Cardiff, focusing on the genetics, morphology, biology and environmental tolerance of gyrodactylids parasitising salmonids.

Dr Bron is continuing a BBSRC-funded project in collaboration with Professor Huw Rees of the University of Liverpool, which seeks to examine, for the first time, differential gene expression in settling copepodid larvae of the salmon louse *Lepeophtheirus salmonis*. The final aim of this work is to isolate and characterise novel targets for vaccines and chemotherapeutants. As part of this work a number of differentially expressed genes have now been identified, which will serve as candidates for further research.



3D-reconstruction of confocal microscope sections of the musculature associated with the principal attachment organ of the parasite *Gyrodactylus*.

In addition to its applications in morphometric analysis, Dr Bron and Dr Shinn continue to explore the potential of image analysis as a means of solving a number of parasitology-based problems. The image analysis system has been effectively used to map and image the surface sensillary structures in monogenean worms using a novel technique for compositing a series of 2-D images. Together they are trying to establish the functional morphology of the attachment organs of *Gyrodactylus* spp. using a range of techniques (SEM, TEM, X-ray elemental analysis and fluorescence microscopy). Further experiments were carried out to evaluate the use of mass spectrometry elemental analysis (ICPMS) as a tool for identifying discrete populations of salmon lice.

Dr Helen Hayes completed her contract to pursue the development of an artificial salmon skin equivalent, which was the subject of a completed PhD project by Ricky Butler under a LINK Aquaculture project in 2001. This work, in collaboration with Dr Bricknell of SOAFED will now be continued by a PhD student, Keith Walton.

The first phase of the BioMarine project was completed highly successfully by Dr Denni Schnapp. This project, to look for potential biocontrol agents for salmon lice, has now been expanded and employs two new post doctoral fellows, Dr Darren Watt and Dr Stephanie Durand. Mark Freeman has now completed his BBSRC Case – supported project looking at the natural pathogens of the salmon lice. Mark has fully described a number of candidates and assessed their potential as biological control agents. He has discovered a new parasite pathogen of the salmon louse, which is both a new genus and new species of microsporidian. Janet Stone continues her work on chemotherapeutants for sea lice at the Machrihanish research station

Nick Taylor has been very active in freshwater fisheries, sampling for freshwater fish lice, *Argulus* spp. Nick, under the supervision of Professor Sommerville and Dr Wootten, is carrying out a quantitative risk assessment sponsored by a number of fisheries' organisations and the Environment Agency. This year's study has identified a number of candidate risk factors which will be explored in 2002-3 with the objective of recommending a management/control strategy for *Argulus* in stillwater fisheries. In parallel with this project, Professor Sommerville has been carrying out trials for Schering Plough to look at the usefulness of Slice (emamectin benzoate) as a treatment for *Argulus* infections.

Continuing a long term programme in myxosporean research, Astrid Holzer, supported by the Austrian Academy of Sciences, has developed *in situ* hybridisation techniques to the extent that she can describe the progress and development of a single sporoplasm from its entry into the external epithelium of the fish, its reproductive phases in different organs, through to its production of spores in the urinary system and release into the environment. Next year she will expand her studies to investigate the relationship between actinosporeans and myxosporeans in the study habitat using molecular techniques. Astrid won first prize for her presentation to the myxosporean workshop associated with the ICOPA meeting in Vancouver.

Phoebe Carter has now completed the experimental work for her BBSRC Case funded project with the Natural History Museum studying the effects of low levels of cadmium on host parasite interactions. The earlier work studying the effects on the gill parasite *Dactylogyrus* spp. was been extended to investigate the impact of cadmium on *Gyrodactylus* and its fish host. A series of experiments studying the impact of this metal on both host and parasite will help to interpret fluctuations in parasite populations.

The Parasitology laboratory has had a busy year with 10 scientists having visited to work on various collaborative projects under the EU Improving Access to Infrastructures Programme. Professor Kalman Molnar, Dr Szekely, Ms Esterbauer and Ms Racz from the Veterinary Medical Research Institute, Hungarian Academy of Sciences, Budapest made three separate visits to the laboratory to work with Astrid Holzer on the development of molecular techniques using *in situ* hybridisation in the study of myxosporeans. In the summer, Mr Jens Sigh from the Institute of Veterinary Microbiology, Royal Veterinary and Agricultural University, Frederiksberg, Denmark studying cytokine expression in the skin of rainbow trout during parasite infections came to use *in situ* hybridisation as an approach to this work. August, however, saw our busiest month with five visitors. Mr Roman Kuchta from the Czech Academy of Sciences, Ceske Budejovice made a return visit to Stirling to work on the diversity and biology of tapeworms of the genus *Eubothrium*. At the same time, Dr Dezfuli, Ms Giari and Ms Simoni from the University of Ferrara and Dr Bosi from the University of Milan, undertook an extensive immunohistochemical study focusing on host tissues at the site of endoparasite attachment. This brings the number of EU scientists visiting the Parasitology Laboratory to more than 15 over the last two years.

Vaccines and Immunology

The Aquatic Vaccine Unit and Aquatic Research Facility (disease aquarium) continue to provide an excellent platform for disease control research which focuses on two main areas of disease control—the development of rapid methods for the detection of fish pathogens, and the development of fish vaccines. Three projects (one funded by the EC and two by LINK Aquaculture) that have recently been completed have led to vaccines (pasteurellosis, BKD and RTFS) that are now being field-tested prior to commercialisation. A Research Development Grant from SHEFC has also enabled the setting up of the Scottish Fish Immunology Centre (SCOTFISH) between the Institute and the School of Biological Sciences at Aberdeen University and the FRS Marine Laboratory, Aberdeen. Equipment has now been installed and this will enable the development of novel multiplex assays for fish. SCOTFISH will provide technical support and training for a variety of immunology projects.

Proliferative kidney disease (PKD) remains an important area of research. This disease, caused by an unusual myxozoan parasite, continues to pose a severe restriction on rainbow trout farming in the UK. Immunological studies/vaccine development and the identification of novel chemotherapeutants for this disease are areas currently being addressed. Dr Morris is working on a DEFRA-funded 3-year project, co-ordinated by Dr Adams, involving collaboration with Professor Secombes at Aberdeen University, the Moredun Research Institute in Edinburgh and Dr Steve Feist at CEFAS, Weymouth. This will provide important data on the immune response of fish to *Tetracapsula bryosalmonae*, the causative agent of PKD. Ultimately it is hoped that by elucidating the nature of immunologically important antigens it will be possible to develop a vaccine for PKD. Mr Charlie McGurk started a NERC CASE funded PhD studentship last year, further examining aspects of vaccine development for this disease. Mr Charlie Morris who completed his PhD work last year was employed as research assistant on an extension to the LINK funded PKD project examining potential chemotherapeutants under the supervision of Drs Adams and Morris. None of these were taken forward, despite their effectiveness at killing the parasite, due to host tissue damage. Additional chemotherapeutants are presently being tested by Mr McGurk.

Most of the other research in the Aquatic Vaccine Unit involves bacterial pathogens (*Renibacterium salmoninarum*, *Photobacterium damsela* subsp. *piscicida*, *Flavobacterium psychrophilum*, *Mycobacterium* spp., *Piscirickettsia salmonis* and *Aeromonas hydrophila*). The project on pasteurellosis vaccine development, funded by the EU AIR programme, awarded to Dr Adams and Professor Richards is now finished. Partners in Greece (University of Patras) and Italy (University of Udine) and industrial partners (AVL and Selonda Aquaculture, Greece) are all now involved in taking the vaccine forward to commercialisation.

The project on bacterial kidney disease (BKD), funded by LINK Aquaculture and co-ordinated by Dr Adams and Professor Richards was given an extension to complete crucial vaccine trials. This research is in collaboration with the University of Plymouth and industry (BTA, SSGA, AVL). Dr Kim Thompson tested the efficacy of recombinant antigens provided by Dr Keirnan at Plymouth. One of the recombinant proteins has yielded promising results and will be taken forward to commercialisation by AVL. On completion of the BKD project Dr Thompson moved to work on the EC funded ISA project in collaboration with Drs Adams and Starkey and is currently developing monoclonal antibodies to ISAV.

The LINK Aquaculture-funded rainbow trout fry syndrome (RTFS) vaccine development project has now been completed. Alpharma Animal Health, industrial partners on the project, will take field trials ahead next year with one of the vaccines developed in the project, in conjunction with Stirling and the BTA.

DNA-based diagnostic tests have now been developed for a variety of fish pathogens, including *F. psychrophilum*, *Piscirickettsia salmonis*, *R. salmoninarum*, *Tetracapsula bryosalmonae*, ISAV, IPNV and *Mycobacterium* spp. These PCR tests are being used in parallel with established antibody-based tests to detect pathogens in fish and the environment. *In situ* hybridisation methods have also been established for the detection of pathogen DNA in fixed tissue sections. The new project on mycobacteriosis, funded by an innovation grant from the University SURE Team to Drs Adams and Thompson, adapted the existing conventional PCR based approach to real-time PCR specifications. Dr Margaret Cairney developed a robust standard test for both identification and quantification of *Mycobacterium marinum*, a bacterial pathogen that is capable of infecting and causing disease in both fish and humans. Further work is continuing to develop similar assays for two other aquatic mycobacteria.

Two PhD students successfully completed their theses this year. Nirattissai Petschupa's project was on the immune response of rainbow trout to *Tetracapsula bryosalmonae* while Emine Turgut's project was on the expression of *Renibacterium salmoninarum* antigens cultured *in vivo* and *in vitro*.

Visiting scientists to the Aquatic Vaccine Unit this year include Dr Galena Jeney, from HAKI, Szarvas, Hungary who was funded by the EC Improving Access to Infrastructures Programme for 3 months to work on sturgeon immunology with Drs Thompson and Adams. Two visitors from China also worked in the laboratory. Dr Jingu Shen from the Institute of Freshwater Fisheries, Shanghai worked on *Aeromonas hydrophila* vaccine development for 6 months, while Dr Houbu Wu stayed for 3 months working on the characterisation of aquatic *Vibrio* species. Ms Kate Ferguson, a student from Dollar Academy also visited the laboratory on a Nuffield bursary and examined the microsporidian parasites of bryozoans.

Commercial activities include feed and vaccine trials in the Aquatic Research Facility, serology services in the Aquatic Vaccine Unit laboratory, and the licensing of antibody producing hybridoma cell lines to Aquatic Diagnostics Ltd. The latter company was set up in December 2001 as a spin-out company from the University, following a SMART award to Dr Adams. The company markets monoclonal antibody probes to detect fish pathogens and immune responses in different species of fish. The antibodies were developed in the Aquatic Vaccine Unit over the last 15 years and the hybridoma cell lines producing the antibodies have been licensed to Aquatic Diagnostics Ltd with royalties paid back to the University. Dr Thompson has been seconded part-time as Technical Director for the company.

Virology

In the previous year, infectious salmon anaemia virus and fish nodaviruses have continued to represent the main research areas of the virology laboratory. Research aimed at the development of real time diagnostic procedures for infectious salmon anaemia virus (ISAV) has continued. These molecular diagnostic procedures enable the detection of specific targets during the process of nucleic acid amplification, without the need for time consuming analyses of reaction products inherent in conventional PCR methods. Real time diagnostic methods have proved to be highly sensitive and specific when used for the detection of human viruses. Establishment of real time diagnostic methods in the virology laboratory will play an important role in the diagnosis of aquatic pathogens. Initial work is aimed at optimising real time RT-PCR detection procedures using molecular beacons for fluorescent detection of ISAV in clinical samples, and will facilitate rapid identification of ISAV isolates prevalent in UK aquaculture.

We have recently developed a real time nucleic acid sequence based amplification (NASBA) procedure for the detection of nodaviruses in clinical samples. NASBA is an isothermal nucleic acid amplification procedure that amplifies RNA directly, and thus is particularly suited to the detection of RNA virus targets such as nodavirus and ISAV. Real time detection in NASBA is achieved through the use of molecular beacons. Initially applied to the detection of fish nodaviruses, the real time NASBA procedure exhibited a wide dynamic range and a high degree of specificity. In preliminary experiments, we have successfully used this procedure to detect nodaviruses in clinical samples from several fish species including sea bass, grouper, Atlantic cod, Dover sole and striped jack. Assays designed to detect other viruses, including infectious pancreatic necrosis virus and sleeping disease virus of rainbow trout are in development.

Work aimed at the characterisation of nodavirus antigenic diversity has continued. Initial objectives include the identification of regions of the nodavirus capsid which are recognised during protective immune responses. The recently developed Luminex technology will be used in this study. This work will involve the production of a panel of monoclonal antibodies against fish nodaviruses, and is a collaborative venture with the Aquatic Vaccine Unit. The results of this study will facilitate the rational design of nodavirus vaccines.

A three year project aimed at the development of vaccines for use in aquaculture has been completed during the previous year. This work was funded by Novartis plc, and formed part of a collaborative project with Dr Nuno dos Santos of the University of Porto and scientists from the University of New Brunswick, Canada. Inactivated whole virus and recombinant protein-based vaccine preparations were produced at Stirling. A study of the protective efficacy of these vaccines, and analysis of immune responses in immunised fish has successfully been completed.

On the basis of these results, Novartis have recently announced their intention to fund this project for a further three years, with the aim of expanding the number of virus targets studied.

The virology laboratory has recently received funding to study pathogenesis and innate immunity in infectious pancreatic necrosis virus (IPNV) infection. IPNV has continued to represent a serious problem to the UK aquaculture industry, and the incidence and severity of this viral disease are increasing. The project will be performed in collaboration with the FRS Marine Laboratory at Aberdeen. Initial work is aimed at the quantitative analysis of markers of the innate immune response during IPNV infection, and an analysis of the genetic basis of virulence in IPNV.

Sleeping disease of rainbow trout is a further area of research due to commence in the virology laboratory in the coming months. Sleeping disease is caused by an atypical alphavirus (SDV). Previously reported in Europe, outbreaks of this disease have recently occurred in Scotland. A PhD student is due to commence work in January 2003 aimed at the development of molecular and serological diagnostic procedures for SDV.

Aquatic epidemiology and population health control

The Institute of Aquaculture is developing a significant profile in the emerging area of aquatic animal epidemiology, through high profile research, publications and membership of organisations such as the International Society for Aquatic Animal Epidemiology.

The successful completion of projects on aquatic epidemiology funded by DFID and population welfare control funded by LINK Aquaculture, has led to a number of activities over the past year. Dr Turnbull, with Dr Chinabut from the Aquatic Animal Health Research Institute (AAHRI), Bangkok, Thailand received further funding from DFID to examine the impact of aquatic animal health control on the livelihoods of poor people in South East Asia. This project focuses specifically on aquatic epidemiology and continues the collaboration with Dr Mohan in Mangalore India, Dr Hao in Ho Chi Minh City and Ms Dung in Can Tho, Vietnam and Professor Morgan from Liverpool University. It has also established a linkage with Dr Stirrat's social development group at Sussex University. From Stirling Dr Crumlish and Dr Corsin have both contributed to the project. This further funding has allowed analyses of the remaining data from the previous epidemiology project on white spot disease of cultured shrimp. These studies contribute not only to the understanding of white spot disease but also to the investigation and control of aquatic animal health at a population level, including a process for extracting and evaluating disease definitions at a population level and practical farm level control strategies.

DFID has also funded a project co-ordinated by Dr Crumlish to study the livelihood implications and control of a serious disease of cultured pangasius catfish in the Mekong Delta of Vietnam. This previously unrecognised condition was identified and described during a previous short study funded by DFID. This project will involve contributions from a variety of disciplines. AAHRI in Bangkok will provide assistance with challenge studies; the Scottish Agricultural Colleges are providing expertise in the social sciences through Dr Smyth, and Professor Young from the Department of Marketing at Stirling is conducting a market analysis at a local and international level. From the Institute of Aquaculture Dr Crumlish is also responsible for much of the biological sampling, bacterial analyses and contributes to the examination of the livelihood implications. Professor Ferguson has examined the pathology associated with the condition and a description of the condition has already been published. Dr

Turnbull has designed and will analyse the data from a longitudinal epidemiological study of the disease in cage-cultured pangasius, Dr Shinn is contributing expertise on associated parasite problems and Dr Thompson has assisted with development of anti-sera.

The application of epidemiological techniques to aquatic animal populations has been advancing in several other areas. There has been continued collaboration with Professor Morgan from the University of Liverpool and Dr Corsin has been employed at Stirling during the past year. Dr Turnbull has applied epidemiological techniques to data supplied by Professor Ferguson from the Diagnostic Unit

The study of aquatic animal welfare has been an area of collaboration between Stirling and the University of Glasgow for more than eight years. A previous LINK Aquaculture funded project on the effects of stocking density and food deprivation on the welfare of farmed Atlantic salmon has been completed. Dr Turnbull was invited to contribute to a positioning paper on fish welfare, commissioned by the Fisheries Society of the British Isles and co-ordinated by Professor Huntingford of the University of Glasgow. Dr Turnbull is now co-supervising Mr North's PhD project on welfare of farmed trout, formally consolidating existing linkages; this project principally supervised by Professor Bromage, is funded by BTA and DEFRA.

Diagnosics

Five hundred and seventy two submissions were received, from a range of different clients in various countries worldwide. Interesting cases over the past year have included the recent diagnosis of sleeping disease in rainbow trout farms in several parts of Scotland. This viral disease, previously reported mostly in France, can cause mortality of up to 70%, and is particularly infectious. Early indications are that we have been successful at recovering the causal alphavirus, which should make the development of diagnostic tests possible. Another disease we have seen in the past, but which seems to be gaining ground, is a filamentous bacterial enteritis, again of rainbow trout, especially in caged loch populations. Once again mortality can be high, and as with sleeping disease, control presents real problems.

Reproduction and Genetics Group

Staff and postgraduate students in Reproduction and Genetics have continued to focus their attentions on the management of broodstock and the production of fish as a controllable and sustainable resource. This involves studies of the control of maturation and puberty, the mechanisms involved in sex differentiation and gender control and the development and management of programmes of selective breeding. All of these areas combine the use of the newer techniques of molecular biology with whole animal studies of physiology and function, in particular where they are relevant to commercial culture. A major thrust in recent years has been the application of this expertise to questions raised by the ever-expanding interests in new aquaculture species and species diversification, particularly with regards to marine fish.

Marine Fish and Maturation

Professor Bromage, Dr Porter and Andrew Davie, a NERC funded PhD student, were awarded two separate British Marine Finfish

Association (BMFA) and Crown Estate Commission (CEC) grants for work on the photoperiodic control of growth and maturation in the Atlantic cod and Atlantic halibut. The project on cod is supporting a long-term photoperiod trial based at the Machrihanish Marine Environmental Research Laboratory in conjunction with Bill Roy and Derek Robertson.

These studies are particularly important because the embryonic cod and halibut industries in Scotland badly need simple non-invasive procedures to control the problems of early maturation of male fish before they reach market size. At the start of August this year Andrew Davie visited the Institute of Marine Research, Bergen, Norway as part of a collaborative Norwegian Research Council award to Professor Geir Lasse Taranger from Bergen and Professor Bromage for studies of light perception in Atlantic salmon and cod. The work is divided between the two Institutes and is investigating the effects of spectral composition and light intensity on melatonin production; melatonin levels change in response to light and dark and hence, are able to provide a most useful and practicable tool for the assessment of how fish see light. There have also been study visits to Stirling by the Bergen groups with the support of the Institute's EU Improving Access to Infrastructures Programme for work on smoltification and the photoperiod control of maturation in cod.

We are also collaborating with Dr Carlos Mazorra, Seafish Industry Authority (SFIA), Ardtoe in an investigation of the seasonal changes in day-night melatonin profiles of both halibut and haddock. The haddock is a most important fish in Scotland and looks likely to be the next marine species to be farmed after the cod, halibut and turbot; it also suffers from similar problems of early male maturation at below market-size.

Recently a major 3-year award from the EC Framework 5 Programme was made to Professor Bromage and colleagues for work on the control of puberty in farmed fish. This will involve collaboration with colleagues in France, Spain, Norway and Holland. It also involves support of the British Trout Association (BTA) and work with a number of salmon farms.

Species Diversification

Dr Rana continued to expand his research portfolio on developing new species and sustainable aquaculture systems. Two new research programmes were initiated this year. An investigation of the constraints in larval production of common snook, *Centropomus undecimalis*, is in collaboration with Dr Kevan Main of the Mote Institute in Florida and Dr Kim Jauncey. In Oman, research on the reproductive biology and mass seed production and marketing issues of the silver sea bream, *Rhabdosargus sarba*, is underway in collaboration with Dr Goddard of Sultan Qaboos University and Professor James Muir.

In March 2002 Dr Rana also visited the Instituto de Investigaciones sobre Recursos Naturales of the Universidad Michoacana de San Nicolás de Hidalgo in Central Mexico on a project to develop appropriate hatchery and seed culture systems for the sustainable aquaculture of an endangered fish species, *Chiostoma estor estor*. A research programme has also commenced in South Africa to evaluate the roles of traditional aquaculture in sustainable rural livelihoods; this will complement recent initiatives on developing urban and peri-urban aquaculture in this country.

Broodstock Nutrition

The effects of dietary arachidonic acid (AA; an essential polyunsaturated fatty acid) on the reproductive performance of broodstock Atlantic halibut and the consequent quality of the

eggs, milt and larvae is being investigated by Emma Alorend with the support of a combined BMFA, Otter Ferry Seafish, CEC, Trouw UK and Nutreco award to Niall Bromage and Gordon Bell. This continues some earlier work on halibut at the Institute supported by the Technology Foresight Programme, which was the subject of a keynote address to the Larvi'01 International Conference in Gent. Results have been most promising with optimised levels of AA improving egg and larval survivals compared with the diets currently being used by the Industry.

Photoperiod and Growth

Funded by grants from NERC (ROPA Award), the BTA and a Broodstock Research Club to Professor Bromage, John Taylor is investigating the influence and interactions of photoperiod, growth factors and energetic status on growth and reproduction of rainbow trout. Findings from these studies have led to the application and investigation of constant light photoperiod regimes under a variety of commercial fish farming systems. These techniques are providing a simple but effective means of improving farm production with significant improvements observed in specific growth rate and feed conversion. A recent innovation has been the establishment of a new assay for one of the growth factors involved in the transmission of information on daylength to the growth axis of fish. This is a most important development for it should enable us to understand how photoperiod and growth interact in the control of maturation.

Photoperiod and Maturation

Iain Berrill has recently completed his PhD project on the environmental influences on growth, precocious maturation, and smoltification in Atlantic salmon, supported by a NERC CASE award to Niall Bromage and Mark Porter in collaboration with Marine Harvest, Scotland. An initial commercial scale photoperiod project, that highlighted the importance of the early developmental period in triggering early maturation, was further investigated through analyses of commercial data. Further trials investigating the effects of feed ration and dietary lipid level were also completed at the Institute of Aquaculture's Buckieburn Freshwater Research Laboratory. This work has provided important information on the multifactorial control of early maturation in salmon.

Antonio Campoza-Mendoza with the support of the Mexican Government has continued his work on the molecular basis for the photoperiod control of reproduction in tilapia. He has recently successfully sequenced the clock and melatonin receptor genes and is now investigating their change in response to photoperiod stimulation.

Welfare and Stocking Density

The DEFRA-BTA funded project investigating the effects of stocking density on the welfare of farmed fish in collaboration with CEFAS Weymouth is now in its second year. An initial trial investigating the effects of different stocking densities of rainbow trout in tanks with identical flow rates assessed fish welfare through the use of the following putative welfare indicators: haematocrit, cortisol, lysozyme activity, plasma glucose and measurements of fin erosion; overall results showed there to be no significant differences in growth and most other parameters over the 9-month period under the different stocking densities, provided that good water quality was maintained. Work is ongoing with a follow-up experiment that is investigating the effects of different rates of water exchange on groups of rainbow trout stocked at the same density. A questionnaire survey of British rainbow trout farms was carried out earlier in the project and is now being backed up with farm visits and analyses of farm data where groups of fish have been followed in a series of different culture systems and at a

range of stocking densities. A novel image analysis system has also been developed to measure fin shape and area under a variety of culture conditions. Collectively these data would suggest that providing certain water quality parameters are maintained then fish welfare would also be safeguarded. Professor Bromage, Ben North and Dr Turnbull and colleagues at Weymouth were invited by DEFRA to give two review papers of this work at a Special Workshop on Fish Welfare which aimed to establish future priorities for fish welfare R and D projects.

Seasonality and Immunology

With the support of a NERC CASE award, supervised by Dr Kim Thompson, Dr Mark Porter and Professor Niall Bromage in collaboration with EWOS, Alison Morgan is investigating the effects of seasonality on the immune response in the rainbow trout. Seasonality dominates the life history of fish, it co-ordinates reproductive activity, affects body weight and condition, food intake and locomotor activity and it co-ordinates the immune system. The effects of photoperiod and melatonin administration on the immune system have been studied through both winter and summer trials carried out at the Buckieburn Freshwater Research Laboratory. Results to date suggest that there is a significant correlation between season and the immune system. Melatonin was also found to significantly enhance phagocytosis in June and fish fed an immunostimulant diet had a significantly higher level of survival following challenge with *Vibrio anguillarum*.

Genetic Maps and Gene Banking

During the past year Margaret Cairney and John Taggart have concluded an EC FAIR funded project (SALGENE) to generate a genetic body map for Atlantic salmon. This was a collaborative project with partners from the Norwegian College of Veterinary Medicine, Oslo, the National University of Ireland, Galway and the Danish Institute of Animal Science, Tjele. The objectives of the 3-year project were to isolate and identify new genes from Atlantic salmon using a strategy based on cloning and characterising expressed sequence tags (ESTs). Stirling's role in the project was to generate and characterise ESTs from spleen and kidney cDNA libraries and to isolate construct subtractive libraries. This has been successfully completed with 2000 ESTs being partially sequenced. The data are currently accessible through GENBANK. Overall the project identified in excess of 8000 unique ESTs, the majority of which are likely to represent individual salmon genes. This has provided the foundation of a valuable resource for future gene expression studies.

Dr Rana was awarded a DFID grant to develop a field gene banking kit and organise an international workshop in collaboration with NAGRI, Thailand on the harmonisation of technologies for broodstock and gamete management for Asia. Two visiting scientists from the Central Institute of Aquaculture, Bhubaneswar, India, were trained under the supervision of Dr Rana over a three-month period on gene banking and broodstock management techniques.

The EU funded BASSMAP project has completed its first year and Dr John Taggart has constructed a bacterial artificial chromosome (BAC) library for seabass which will contain at least 6 copies of the bass genome divided up into 150 kilobase pair lengths contained in a bacterial vector. To make this library more useful German collaborators will take a sample of each of the 50,000 + bacterial colonies grown separately and transfer or grid these on to nylon filters. When this is complete it will be possible to probe the filters with a wide range of markers or gene sequences and identify the colonies that contain that gene. This will enable individual genes to be isolated much more easily and will assist in the development of a gene map for this species.

Copies of the library and the filters will be supplied to the other partners in the project so that they can identify and isolate the genes of particular interest to them.

Genetic Diversity

John Taggart has also been associated with another EU funded project recently completed: "Genetic diversity in the European lobster (*Homarus gammarus*): population structure and impacts of stock enhancement (GEL)". His role was, primarily, to evaluate the use of genetic tagging (microsatellites) for determining the contribution of ranched individuals in mixed wild and ranched lobster harvests. Computer modelling and monitoring of an existing ranching experiment in Kvitsøy, Norway, concluded that screening with microsatellite markers developed within the project were both feasible and advantageous. A summary of the entire project can be found at <http://www.qub.ac.uk/bb/prodoh/gel/gel.html>.

Selective Breeding

A major area of current and future research initiated principally by Professor McAndrew, is the use of genetic molecular markers in the management of selective breeding programmes for a number of farmed fish, including salmon, trout, sea bass, halibut, sea bream and cod.

The LINK Aquaculture project on the selective improvement of rainbow trout has been analysing the levels of molecular variation in UK rainbow trout strains using microsatellite loci. Two different multiplex systems using 6 different loci have been developed and tested. These will be used to genotype all the broodstock involved in a number of breeding programmes in the winter of 2002. The offspring from the broodstock will be ongrown under commercial conditions. These fish will be analysed for a range of growth parameters at 5-10g and small tissue samples collected so individuals can be genotyped and their family relationships identified. A proportion of these will be PIT tagged so that subsequent performance can be assessed in each individual. Over 400 different families will be followed; this will generate data about the genetic value of individual fish and their respective family for a range of traits including growth rate and disease resistance.

Two similar PhD studies are already underway on seabream in Cyprus and Atlantic halibut in Scotland. The very different life cycle characteristics of these two species raise a whole range of difficulties in designing appropriate breeding and improvement programmes. However, using a combination of genetic fingerprinting and PIT tagging it is possible to design very flexible programmes that minimise inbreeding and maximise genetic gain.

The DFID AFGRP-funded project on genetic management and improvement of exotic (i.e. non-indigenous) carp species in Asian aquaculture, awarded to Dr David Penman and Professor Brendan McAndrew with colleagues from UW Swansea, BFRI and DOF Bangladesh, the University of Agricultural Sciences, Bangalore, India and RIA 1, Vietnam, has reached its mid-point. Dr John Taggart and Dr Margaret Cairney have been involved in the development and application of microsatellite loci. Exotic cyprinid species are of particular importance to aquaculture and poor people's livelihoods in several Asian countries, and the project aims to develop appropriate strategies for their genetic management and improvement. Our main specific activities involve the genetic management of Chinese carp stocks in Bangladesh and the development of a breeding programme for common carp in Karnataka, India. The project held a Workshop in Dhaka in February, the proceedings of which have now been published; Dave Penman and Brendan McAndrew also visited

counterpart institutes in Bangladesh and India during the year to coordinate the work.

Over the past 5 years there have been significant achievements in the development of fully inbred clonal lines of tilapia at the Institute. F₁ crosses are now being evaluated as control lines in a selective breeding programme, funded by a DFID-Competitive Research Facility-funded project with ICLARM and FRI, Malaysia, UW Swansea and CLSU, the Philippines.

Sex Chromosomes and Gender Control

Dr Simon Harvey, with technical assistance from Mrs Ann Gilmour, has continued to work on the BBSRC-funded project on molecular-cytogenetic analysis of sex determination in tilapia, awarded to Dr David Penman and Professor Niall Bromage of the Institute of Aquaculture and Dr Darren Griffin of Brunel University. We have been able to demonstrate for the first time that there are significant sequence differences between the X and Y chromosomes of *O. niloticus*. This involved developing DNA FISH probes from the X and Y chromosomes by microdissection, then amplification and labelling by PCR. Sequencing of the amplified DNA also revealed the presence of several transposable elements, which are being characterised with a view to studying their role in sex chromosome evolution.

In addition to work on the BBSRC-funded project, the past year has also seen significant technical progress in our ability to physically map genes in tilapia, using a bacterial artificial chromosome (BAC) library. This has already allowed us to exclude the aromatase genes from the list of possible major sex determination genes and, using a novel method of chromosome preparation, to accurately map these genes on their respective chromosomes. Some interesting results have also been produced from studies of karyotype evolution in the tilapia. The karyotype of *Oreochromis karongae* (2n = 38) differs significantly from that of most other *Oreochromis* species (2n = 44), as a consequence of three chromosome fusions.

Rafael Campos-Ramos recently completed his PhD on the synaptonemal complex and analysis of sex chromosomes in the genus *Oreochromis*. One of the major findings of this research, which analysed chromosome pairing during meiosis, is that the sex chromosomes of three different species within this genus of tilapia were the largest pair of chromosomes. In a similar area, Md Tariq Ezaz successfully developed and characterised sex-linked DNA markers in the Nile tilapia by screening DNA from XX and YY individuals using AFLP markers. This work is being further extended by Chuta Boonphakdee in her study of the physical mapping of sex-linked and potentially sex-determining genes and DNA sequences in tilapias.

Collectively these studies are providing important insights into the ways in which sex chromosomes have evolved in fish. On a more practical note they are providing the basis for future initiatives, which will enable farmers to sex fish before they begin sexual maturation. It should also allow gender to be easily controlled for most farmed species.

Molecular Genetics

During the past year, the Molecular Genetics research group led by Professor Alan Teale has concentrated in four areas – molecular genetics of fatty acid synthesis, antibiotic resistance, alternatives to antibiotics in aquaculture systems, and molecular genetics of parasite-to-host adaptation.

The research on fatty acid synthesis has continued in close collaboration with the Nutrition Group, and a number of

significant advances have been made. Since the first description by the group of the functional characterisation of a fish desaturase gene, and demonstration of its unusual substrate range, Dr Morris Agaba, Dr Xiaozhong Zheng, Ms Cathryn Dickson and Ms Nicola Hastings have isolated and functionally characterised further desaturases and a number of fish elongase genes from various species. These genes and their products are being subjected to detailed analysis with a view to making structure-function linkages, and shedding light on the evolution of the polyunsaturated fatty acid synthesis pathway in vertebrates. The studies have also contributed to basic knowledge of the steps in the pathway that are involved in synthesis of functional highly unsaturated fatty acids from their dietary precursors. This aspect of the group's research is set to expand significantly in 2003 with the award to Professor Teale and Dr Douglas Tocher of a major new grant by the BBSRC under its Exploiting Genomics Initiative. The BBSRC-funded project will seek genes that alter expression in response to changing levels of dietary polyunsaturated fatty acids, and will construct and make use of an extensive microarray representing large numbers of Atlantic salmon genes. The array will be established at the Roslin Institute, and will be used by collaborating research groups in the Universities of Aberdeen and Cardiff to identify genes involved in other important aspects of salmon physiology and immunology. Qiagen Ltd and Marine Harvest are industrial partners in the project, which has the formal support of Scottish Quality Salmon. The ultimate objective is to develop a new generation molecular genetic tool for health and performance monitoring that will enable assessment of the functioning of a range of key reporter genes in target species on an ongoing basis. This £1.1M project will be co-ordinated by Professor Teale.

A BBSRC-funded project to examine the potential of bacteriophages to protect fish from bacterial pathogens was completed in 2002. No evidence of protection was found using bacteriophages inoculated into fish, but the utility of bacteriophages delivered to the fish culture environment remains to be determined. Dr Marianne Pearson, who had been involved in this project since its inception, left the Institute in January to take up a position in the aquaculture industry. Ms Liz Haughey, as the technician on the project, played a key role in bringing it to a satisfactory conclusion.

Dr Kerry Bartie joined the group in February 2002 to undertake research as part of the EU-funded project, *Asiassist*. This project, which is co-ordinated by Professor Teale, began in December 2001 and is examining the extent and nature of resistance to antibiotics in aquaculture environments in South East Asia, and the risk it poses to consumers and farmers. The project is a collaborative effort involving partners in the University of Cantho in Vietnam, University Putra Malaysia, AAHRI in Thailand, the University of Gent in Belgium and RILAB in Genoa. Standard operating procedures for environmental sampling for bacteria and for the processing of isolates have been developed, and a collection of antibiotic resistant isolates is currently being made. Molecular genetic analysis of the nature of resistance in the various isolates will be a key responsibility of the Stirling group in the coming year.

Professor Teale has been appointed to the BBSRC Animal Sciences Committee. He has also undertaken to serve as joint Co-ordinator, together with Dr Melody Clark of the Human Genome Mapping Project, of the Fish Users Group of ARK-Genomics (the UK Research Council-funded Centre for Investigating Gene Function in Agricultural Species).

Nutrition Group

Lipid Nutrition

The lipid nutrition group continue to research the requirements, metabolism and function of polyunsaturated fatty acids (PUFA) in aquatic organisms. A major part of the research programme is focussed on investigating the effects of substitution of fish oil with vegetable oils in the diets of farmed fish, particularly Atlantic salmon. This involves Gordon Bell, Douglas Tocher, Michael Bell, James Dick, James Henderson, Fiona McGhee, Joanne Good and Jorge Fonseca-Madrigal and several individual projects. One major trial, conducted in collaboration with Ewos Innovation Ltd, has been completed and involved feeding post-smolts of 120g one of 10 diets with various combinations of fish oil (FO), linseed oil (LO) and rapeseed oil (RO). The diets were 100% FO, LO or RO, FO/LO (2:1 and 1:2), FO/RO (2:1 and 1:2), LO/RO (2:1 and 1:2) and FO/LO/RO (1:1:1). After a 50 week feeding period samples of liver and flesh were collected for fatty acid analysis and the effects of diet on hepatocyte fatty acid desaturation activity were measured. Similar measurements were performed in fish fed the 100% FO, LO and RO groups following a 20 week "washout period" with fish oil. The results showed highly significant positive correlations between dietary linoleic acid (LA; 18:2n-6) and linolenic acid (LNA; 18:3n-3) inclusion (derived from vegetable oils) and fatty acid desaturation activity while docosahexaenoic acid (DHA; 22:6n-3) and eicosapentaenoic acid (EPA; 20:5n-3) (derived from fish oil) were negatively correlated with desaturation activity. The results of this trial will be submitted for publication in the near future.

A very large programme, "Researching Alternatives to Fish Oil in Aquaculture (RAFOA)" funded by the EU Framework 5 Programme is progressing well. The first phase involved feeding 75g post-smolts graded levels of LO up to harvest weight followed by a six month washout period. The diets used were 25, 50, 75 and 100% LO in comparison to a 100% FO control. The inclusion of LO did not affect growth rate or feed conversion. Deposition of fatty acids in the flesh and liver was closely correlated with dietary fatty acids resulting in accumulation of LA and LNA and reduction in EPA and DHA with increasing LO inclusion. There was also a tendency for more lipid to be deposited in the flesh, and to a greater extent, the liver with increasing dietary LO. Hepatic fatty acid desaturation and elongation activities were increased with inclusion of LO but activities tended to reduce with increasing age/size of fish. Concentrations of the prostaglandins, PGE₂ and PGF_{2α} were reduced in plasma and gill cells, respectively, with high levels of LO inclusion. In addition several parameters of non-specific immune function were affected by inclusion of LO. Taste panels conducted on fresh and smoked salmon suggested that fish fed 25 or 75% LO were favoured over FO fish in fresh samples and that fish fed 25 or 50% LO were preferred, or rated similar to FO fish in smoked samples. In the second stage of the RAFOA trials a diet containing a blend of vegetable oils (RO, LO and palm oil) and FO (75/25 w/w) will be fed to replicate groups of salmon from first feeding through to harvest, followed by washout. The blend of vegetable oils has been chosen to match the ratio of saturated, monounsaturated and polyunsaturated fatty acids found in fish oils. The trial was begun in March 2002 with first feeding fry and both groups showed good growth. The parr will smolt around March/April 2003 and will be transferred to Loch Duich for on-growing. In addition to the measurements performed in RAFOA I the fatty acid desaturase activities in fry and parr in RAFOA II will be measured using the stable deuterium isotope method developed by Mike Bell. The relative activities using this technique have been similar to those found with the hepatocyte assay, although the ability of fish to synthesise DHA appears to decrease very rapidly during early development.

The combined effects of replacement of fish oil with vegetable oil and high energy diets has been studied in a project funded by NERC LINK Aquaculture, "Fish Oil Substitution in Salmonids (FOSIS)". Four diets have been fed to salmon fry since late March 2000 following yolk-sac absorption. The 4 diets were 1) low fish oil, LFO; 2) high fish oil, HFO; 3) low vegetable oil, LVO; 4) high vegetable oil, HVO. The vegetable oil was a blend (1:1 w/w) of RO and LO. The fish were transferred to a sea water on-growing site at Loch Duich in early April 2001 and were harvested in June 2002 having reached 2 kg. A sub-group from each treatment will be grown until December 2002 with a diet containing FO alone. The growth data show significant differences between fish fed high and low oil levels but no differences between fish fed FO or VO at the high oil inclusion level. Measurement of plasma leptin concentrations, a hormone produced in relation to body fat deposition, showed a correlation with carcass lipid content in fish fed the VO diets but not with those fed the FO diets. A similar effect on leptin concentrations has also been observed in rats. Parameters of immune function were measured in parr and following transfer to sea water the on-grown fish were sampled again in early March 2002. No significant differences were found when comparing total leukocyte and total erythrocyte counts between the dietary groups. Significant differences were found in haematocrit percentages ($P < 0.02$). The LVO group showed significantly reduced haematocrit percentages when compared to both the LFO and HFO dietary groups. The HVO group also showed a significantly reduced percentage of packed red blood cells when compared to the HFO fish. Both the LVO and HVO fish showed significantly reduced macrophage activity compared to both the LFO and HFO groups ($P < 0.0001$). Results for total lysozyme activity, differential leukocyte counts and PGE_2 levels have still to be completed and reported. While these immune parameters have been altered by feeding VO-containing diets there is no evidence to suggest that this has made these fish less resistant to a pathogenic challenge. In addition, the diets used had a complete substitution of FO with VO and this is unlikely to be replicated in a commercial situation in the foreseeable future, although partial substitution of FO is likely to be permitted in the Scottish industry soon.

In all the above projects, an important factor has been determining the ability of the fish to produce long-chain PUFA, especially EPA and DHA, from the fatty acids found in VO. Thus, fatty acyl desaturation and elongation have been measured in isolated hepatocytes and a consistent observation is that the activity of this pathway is increased in salmon fed VO. However, the increased activity is insufficient to prevent the reduction in EPA and DHA and the increase in LA and LNA in tissue lipids. Studies have continued to investigate the factors determining the rate of synthesis of DHA from LNA *in vivo* using a deuterated tracer and quantitation by GC-MS. A number of conclusions from this work are relevant to attempts to try and enhance the rate of DHA synthesis from VO and spare the use of FO and fish meal in salmonid diets; (i) synthesis is normally low in the presence of FO and fish meal (i.e. with all commercial diets) and so all the FO and virtually all the fish meal has to be removed in order to substantially enhance DHA synthesis; (ii) the ability of the fish to synthesise DHA decreases very rapidly during early development; (iii) the rate of synthesis of DHA from LNA in fish reared on VO diets is insufficient to give accumulation of EPA and DHA in flesh triacylglycerols; (iv) most LNA in VO diets is oxidised and unavailable for DHA synthesis. Another interesting finding from the *in vivo* studies was that intestinal tissues, particularly pyloric caeca, were shown to be an equally important site as liver for DHA synthesis. This was an important result as intestine will be the first tissue to be affected by dietary changes, such as feeding VO. Thus, the roles of intestinal tissues in fatty

acid metabolism including desaturation/elongation and oxidation, and the effects of feeding VO, are being studied in a separate project through a studentship to Mr Jorge Fonseca-Madrugal under the supervision of Douglas Tocher.

In addition to these dietary trial led projects, the lipid nutrition group continues to investigate the basic mechanisms underpinning the applied studies through molecular studies aiming to identify and characterise the factors controlling and regulating PUFA metabolism and deposition in fish. The fatty acid desaturation programme aims to clone and characterize enzymes of paramount importance in the conversion of LNA to EPA and DHA and is being pursued by Dr Douglas Tocher in collaboration with Professor Alan Teale, Dr Morris Agaba and Mrs Cathryn Dickson of the Molecular Genetics group of the Institute along with a joint Ph.D student, Ms Nicola Hastings. Fatty acyl desaturases have been cloned and functionally characterized from a variety of fish species including zebrafish, tilapia and carp. Similarly fatty acyl elongases have been cloned from both freshwater species including zebrafish, tilapia, catfish and carp, and marine species including turbot, sea bream and cod. A desaturase and an elongase have been cloned from our primary target species, Atlantic salmon. Although all fish desaturase cDNAs were cloned on the basis of similarity to mammalian $\Delta 6$ desaturase, all the cDNAs encode enzymes which display both $\Delta 6$ and $\Delta 5$ activities when expressed in *Saccharomyces cerevisiae*. In addition, the $\Delta 6$ activity of the zebrafish gene accepted both C_{18} and C_{24} substrates indicating that it was the only desaturase required to produce DHA from LNA. Similarly, functional expression of the elongase gene from zebrafish showed that it could elongate C_{18} , C_{20} and C_{22} PUFA substrates indicating that a single gene product could perform all the elongation steps required for the production of DHA from LNA. Functional expression of the salmon desaturase and elongase genes continues but preliminary data suggest that they may express the same range of activities as the zebrafish genes, indicating that only one desaturase gene and one elongase gene are necessary for the production of DHA from LNA in Atlantic salmon. However, the search for further fish desaturase and elongase genes is continuing through an EU-funded post-doctoral researcher, Dr Xiaozhong Zheng who is also studying the expression of fatty acyl desaturase and elongase genes in salmon fed VO diets through real time PCR and mini arrays. These molecular studies will facilitate understanding of the mechanisms underpinning the nutritional regulation of fatty acyl desaturation and elongation in response to feeding VO and will also help to elucidate the differences in the pathway between freshwater/salmonid fish, which can thrive on diets containing VO, and marine species which must have dietary FO for growth and survival.

Peroxisomal proliferator activated receptors (PPARs) are a family of nuclear hormone receptors known to have various important roles in regulating lipid metabolism in animals, specifically in the regulation of genes involved in fatty acid oxidation and adipogenesis. The role of PPARs in controlling lipid and fatty acid metabolism in fish, particularly in relation to high energy diets and FO replacement, is being studied by Drs Michael Leaver and Douglas Tocher. The role of PPARs in regulating lipid metabolism in fish using plaice as a model species is being investigated in a BBSRC-funded project. Plaice PPAR α , PPAR β/δ and PPAR δ genes have been cloned and sequenced, their corresponding cDNAs have been isolated, tissue expression profiles have been determined and they are in the process of being functionally characterised. In a related project, the role of PPARs in Atlantic salmon is being studied in an EU Framework

5-funded multi-partner project that is also studying sea bream and sea bass. The work on salmon PPARs is largely being undertaken by Dr Tariq Ezaz and he has isolated genes for four salmon PPARs, corresponding to α , δ and two β proteins. cDNAs for these genes are being isolated and these will also be functionally characterised.

The Nutrition Group forms an integral part of a European thematic network, "Fish Oil and Meal Replacement (FORM)" funded by the EU Framework 5 Programme that will run for four years from October 2002. The Network's remit is to address the following specific issues; (a) alternative feed resources – influences on feed consumption, protein and lipid metabolism, physiological changes and fish quality, (b) feed resources – with special focus on genetically modified ingredients and/or ingredients derived from genetically modified plants or micro-organisms vs genetic modification of the produced species themselves, (c) seafood safety – with special focus on dioxins and other potential hazardous substances and (d) healthy eating – with special focus on product tailoring.

Although salmon is the primary focus of the Nutrition Group, marine fish nutrition remains an important area that will continue to expand and two projects currently address the role of arachidonic acid (AA; 20:4n-6) in marine fish nutrition. The importance of providing optimal broodstock nutrition for obtaining maximum egg and larval quality is well established, as is the importance of both EPA and especially DHA in early larval development. However, the importance of the third bioactive EFA, AA, has been neglected. In a PhD project undertaken by Emma Alorend and supervised by Dr Gordon Bell and Professor Niall Bromage, the importance of AA in egg and larval quality is being investigated at Otter Ferry Seafish, jointly funded by the British Marine Finfish Association, The Crown Estates Commissioners, Trouw Aquaculture and Otter Ferry Seafish. However, the importance of AA in fish nutrition in general has been somewhat neglected. In 1994, during a sabbatical to Stirling, Dr John Castell established, for the first time in a marine species, that AA was required by turbot for optimal growth and development and that above minimal requirement levels it stimulated growth rate. These initial studies were conducted using purified diets and pure fatty acids. Recent studies have confirmed a role for AA in the culture of marine fish larvae, especially with respect to early growth rates and stress resistance. Thus, the role of AA in on-growing commercial diets containing AA-rich triglyceride oil produced by fungal fermentation, is being investigated in turbot by Gordon Bell in a study sponsored by DSM Food Specialties, Delft, The Netherlands.

At the present time dumping of highly nitrogenous waste from fish processing factories can place an unacceptable burden on water quality. Recently EU restrictions on the dumping of organic waste have been tightened and new methodology to recover the waste from shrimp and prawn processing has been developed. In pilot-scale facilities waste material has been concentrated into a Protein Omega Concentrate (POC) which is rich in protein, essential fatty acids and carotenoids. An EU-funded CRAFT project, BYPROFEED, will use POC collected and concentrated by different techniques and test its suitability for use as a replacement for fish meals, FO and carotenoids in commercial aquaculture feeds. This 2 year programme involving Gordon Bell and Fiona McGhee will study the inclusion of POC in feeds for Atlantic salmon parr, Arctic char, halibut first feeders and juveniles, and lobster juveniles.

The Nutrition Group also provides a commercial analytical service that has recently been renamed Nutritional Analytical Services.

The NAS expertise is increasingly in demand for analyses of constituents of fish feed and tissues, mostly fatty acids, vitamins and carotenoid pigments. Mrs Liz MacKinlay has been employed for the last 2 years to support the increasing level of commercial contract analysis being undertaken by the group. The success of NAS has led to the recent employment of Mrs Irene Younger. The NAS has taken part in the Roche ring test for carotenoid analysis for the past 4 years. This involves inter-laboratory analysis of samples prepared by Hoffman La Roche and distributed to over 40 participating analytical laboratories worldwide.

Diets for new aquaculture species

The diverse research interests of Dr Jauncey's research students have been maintained. Mohammed Zulfikar Ali successfully defended his thesis on protein to energy ratio and feeding strategy optimisation in African catfish during the year and some interesting results are in preparation for publication. Charles Mahika also successfully defended his thesis on feeding strategies for tilapias in ponds using locally available raw materials. Laura Halfyard has virtually completed her studies (as a part-time external student at the University of St. Johns, Newfoundland) on the nutrition and husbandry of early life-history wolffish while Noe Sanchez-Perez has completed the research phase of his studies into fatty acid oxidation of aquaculture feeds – its measurement and biological effects in shrimp.

As part of the British Council link "Development of sustainable aquaculture of an endangered fish species, *Chirostoma estor*, in a marginalized and impoverished indigenous community from Pátzcuaro, Central Mexico" Dr Jauncey visited Morelia in Mexico (Instituto de Investigaciones sobre Recursos Naturales (INIRENA), Universidad Michoacana de San Nicolás de Hidalgo UMSNH for 2 weeks in to assist in development of nutrition research.

Environment Group

Environmental Services

Strategic environmental planning and management is becoming ever more important to the aquaculture industry due to increased regulatory and market pressure and environmental awareness. The expansion of aquaculture throughout the world requires more effective use of available environmental carrying capacity. This is true not only of Europe, but also in developing countries and has increased the need for consultancy services as provided by Environmental Services, which specializes in aquaculture and the environment and sustainability issues. Consequently, Environmental Services has again had a busy year consolidating the previous successes and widening its field of operations.

The beginning of the year saw staff changes within Environmental Services. Dr Karen Robinson and Ms Annie Moodie have left and been replaced by Dr Stuart Bell and Dr Garnet Hooper. Their expertise has enabled routine work to be maintained to a very high standard while bringing other, new skills to our consultancy services thus widening our portfolio in the aquaculture sector.

Routine freshwater analysis has remained consistent over the years and Environmental Services has maintained a large presence in the Scottish freshwater industry. Over the past year more of this work has also involved consultation and review with the Scottish Environment Protection Agency on behalf of clients



Deployment of self recording current meters for hydrographic measurement.

on regulatory issues. The model developed for calculation of dilution and dispersion of an anti-microbial treatment in freshwaters has been completed and accepted as a tool for environmental regulation.

Marine work has continued at a high level with ever increasing requirements for environmental monitoring and survey. The nature of the work, however, is changing with analysis and laboratory processing of marine derived samples considerably increased. Also, hydrographic survey, modelling and submission of environmental impact assessments are becoming commonplace and forming a larger part of the consultancy work. Additionally, environmental monitoring is becoming more strategic within the industry, and Environmental Services is now contracted to monitor and supply environmental management advice to 5 of the largest aquaculture groups in Scotland and one in Ireland, as well as providing individual contract services to an increasing client list. As in previous years, work is largely based in Western Europe, however more overseas projects are being undertaken, including environmental impact assessments in Brunei and Sierra Leone.

Contract research is also within the remit of the Environmental Services. One such project involves investigating the effectiveness of a novel, non-toxic anti-foulant coating on marine fish-cage nets. Excellent results were achieved against mussel attachment. Future work will involve investigation of seaweed fouling and field studies under commercial use conditions.

The waste dispersion models under development within the Environment and Systems Groups (with Professor Lindsay Ross) have been taken to a second generation by Mr Adam Brooker. He has improved significantly on the basic model, incorporating the work of Dr Oscar Perez and Dr Yrong Song Chen and integrating it entirely into the framework of a geographic information system (GIS). This allows its use for estimating the dispersion of marine cage waste for environmental regulation and to implement a GIS based coastal zone management system capable of integrated management of large areas of coasts and better use of carrying capacities by aiding manipulation of other sea and land-based data. It is ideally suited to environmental management around area management criteria required for the implementation of future EU regulation. It is hoped that the project will be developed further in future and additional funding is being sought.

This year saw the completion of a PhD project investigating the impacts of parasiticide treatments on zooplankton populations. It has been very successful with new methods for laboratory ecotoxicology assessment for copepods being developed using sub-lethal behavioural end-points, and field based mesocosm techniques developed and tested. This adds considerably to existing knowledge of environmental effects and fates of these chemical treatments and provides a useful monitoring tool.

Mr Richard Corner has been investigating the environmental benefits of adaptive feeding technology in Scottish waters under a NERC CASE award. The project has ended its second year, and field work is near completion. Mr Corner won the Scottish Association of Marine Science Prize for the best postgraduate student presentation at a national research meeting of the Scottish Marine Group in Aberdeen.

Ms Malene Felsing has completed her field work and is nearing completion of her project to investigate environmental impacts of aquaculture using an experimental approach. This is a split centre PhD project between the University of Stirling and the Nutrition Group of Fisheries, Western Australia, based in Perth. Several, highly successful aspects of cage waste impacts have been investigated, including uptake by indigenous fish. This will have important implications for aquaculture waste management and implications for modelling of solid waste dispersion and its environmental fate.

Mr Stephen Cross, based in British Columbia, is continuing to investigate the integration of different aquaculture practices and its effect on both the environment and socio-economics of local first nation populations. Routine environmental monitoring is undertaken to investigate the impacts of large scale aquaculture on smaller scale projects with a view to their potential for integration and cooperation. The project is in conjunction with Professor James Muir.

Antifoulants are commonly used to prevent the settlement of seaweeds and mussels on marine fish-cage nets. These are often copper-based which can be toxic and persistent in the environment. A PhD study to trace the amounts of copper in sediments and in fauna near to fish cages has been completed by Mr Gernot Vonhoegen. The project traced the fate and uptake of various copper species within sediments and tissues of benthic fauna. Results suggested that there could be significant sublethal effects, thus indirectly affecting bio-processing of waste nutrients.

The expansion of aquaculture means that effective use of carrying capacity of the environment in developing countries is essential for maintenance of environmental goods and services. One of the main problems is defining the capacity and finding reliable indicators of capacity use. The TROPICA project is a DFID funded initiative (collaboration between Dr Trevor Telfer and Nautilus Consultants Ltd) to define indicators to measure when environmental carrying capacity limits for aquaculture in Vietnam and Bangladesh are being approached or exceeded. These indicators will be defined from a mixture of desk study and field work investigations, and validated under local conditions. The project began in 2001 and runs for three years. Initial workshops in Vietnam and Bangladesh have consolidated the study programme and field methodology.

Dr Nigel Willby has recently joined the Environment Group within the Institute completing a NERC Postdoctoral Fellowship in September 2002. His main interests are in aquatic and functional ecology and biomonitoring. During this time he has

worked mainly on the effects of flow regulation on longitudinal gradients in biodiversity in British rivers and the application of functional and trait-based approaches to biomonitoring techniques based on aquatic vegetation. Thanks to a NERC new investigators grant he has also been collaborating over the last 2 years with staff in the Laboratoire d'Ecologie des Hydrosystèmes Fluviaux at the University of Lyon on the relationship between propagule banks and the dynamics of floodplain vegetation and the potential role of propagule banks in floodplain restoration. Last autumn he received support from CNRS as a guest researcher at the University of Lyon to pursue collaborative work on aquatic plant palatability to invertebrate grazers in relation to herbivore activity in natural river systems.

Dr Willby has also worked recently on a number of commissioned research projects including: the development of models to predict the potential impacts of renewed boat traffic on the nature conservation value of canals (British Waterways); monitoring protocols for rare aquatic plants (LIFE, UK); the hydrological impacts of beaver reintroduction to Scotland (Scottish Natural Heritage); and the biotic recovery of a newly engineered river diversion (Morrison Engineering). The latter two projects are being continued as jointly supervised PhD studentships based in the Department of Environmental Science with support from the Faculty of Natural Sciences, NERC and SNH.

Ecotoxicology

Dr Baird's ecotoxicology research group has continued to gain international exposure in the increasingly important area of multiple stress impacts on aquatic ecosystems. Following on from a highly successful NERC-funded project whose final results were presented in an invited talk by Dr Baird at the Royal Society in September 2001, the EU-funded TARGET project (www.target-eu.org) on assessing functional capacity within river ecosystems has successfully completed its final field season. This project is developing ecosystem function methods (feeding bioassays with river invertebrates) for use in relation to the European Water Framework Directive (see also below). A second project in this area began in January 2002: the EC INCO-DEV funded MAMAS (www.mamas-project.org) project is a collaboration between scientists in the Systems Group (Dr Little) and the Ecotox Group. This project asks the question: do pesticide inputs from tropical agricultural systems pose risks to sustainable fisheries and ultimately to consumers? At European level, the project is a collaboration between scientists in ALTEIRA, Netherlands and the University of Aveiro in Portugal, and in SE Asia, involves the University of Kasetsart and the Asian Institute of Technology, Thailand, and the University of Peradeniya National Aquatic Resources Agency, Sri Lanka. Several field visits have already taken place to both Sri Lanka and Thailand, including workshops involving Dr Graeme Taylor and PhD students Garry Milwain and Kreingkrai Satapornvanit. 2002 also saw the completion of the EC INCO-DEV TROCA-WET project (www.troca-wet.org) on pesticide impacts on tropical wetlands. Dr Baird travelled to workshops in Mexico and Costa Rica, which concluded with a forward plan to develop a research network in Central America focusing on ecological risk management of pesticides.

Further highlights in what has been a very successful year for Dr Baird's group were the visits of several overseas researchers to work with his team: these included Dr Carlos Barata (IIQAB-CSIC Barcelona, Spain) and Silvia Gonzaga (University of Aveiro, Portugal) through the EC Improving Access to Infrastructures Programme, and Dr Fred Wrona, Environment Canada, who is also an Honorary Lecturer at the Institute. Further overseas collaboration was undertaken with a new project at the University of New Brunswick, supported by Environment Canada. Dr Baird

visited both campuses in February 2002 to give invited presentations, followed by a further visit in June with Phil Williams, a NERC CASE PhD student, to scope out field sites for deployment of sediment bioassays to assess pesticide runoff from agricultural areas. David Riddell, another NERC CASE student with Dr Baird and Environment Canada also carried out field work in New Brunswick on the effects of metal mining on salmonid foraging behaviour, which he presented at the SETAC Europe Congress in Vienna in May 2002.

Following a successful Science Research Infrastructure (SRIF) bid in 2001, Dr Baird's lab now has additional capacity in the area of pesticide analysis, with the purchase of a new HPLC system with fluorescence detection, together with a PAM field fluorometer for use in primary production studies, and which was the focus of a study visit by Silvia Gonzaga under the EC Improving Access to Infrastructures programme over the summer of 2002.

Environmental pollution by industrial chemicals and agrochemicals is an ongoing concern worldwide and whilst developed countries can afford to strongly regulate usage and discharges, in many other countries with serious population pressures and weaker economies there is of necessity much less control when cash crops and human disease are of prime importance. There is growing concern that not only is the aquatic ecosystem at risk but that contaminants may enter the human food chain and cause harmful effects, this is exemplified by the recent rulings of the EU on levels of dioxins in foods, which has led to a reappraisal of food sources for aquaculture species to produce fish with acceptable dioxin levels.

Through the SRIF initiative we have acquired new and updated analytical facilities for chemical and enzymatic analysis which will enable us to significantly improve our capabilities in this area. We are constructing a new positive pressure "clean lab" for extraction of low levels of contaminants such as pesticides, polyaromatic hydrocarbons, dioxins and pcbs from environmental samples, wild biota, aquaculture feeds and products and have updated instrumentation for chromatographic and spectrometric analysis of these compounds by acquisition of new HPLC and GC-MS instruments and a scanning fluorescence/luminescence spectrometer to add to the complement of instruments we already have. Another approach to contaminant effects measurements pioneered by Professor George's group and other international collaborators over the past two decades has been to use reporter gene assays both in cell culture (*in vitro* toxicology) and in animal tissues, to assess biological effects and bioavailability of contaminants. Over the past year, with the assistance of Dr Maria Ruiz-Leal, a visiting lecturer from the University of Valencia in Spain, we have adapted a number of our enzymatic, metabolite and immunoassays to new high throughput microplate instrumentation purchased with the SRIF initiative to increase our capability for determination of effects at the sublethal level as early warning systems for the adverse health of fish.

DEFRA have recently funded a consortium (the UK National Marine Pollution Monitoring Management Ecotoxicology Analytical Quality Control Group!) comprising of Professor George, CEFAS, FRS, EA, NIEA and SEPA to apply these biological effects measurements to assess impacts of PAHs and dioxins, heavy metals and endocrine disruptive compounds on fish (flounder are the sentinel species) in 12 major UK estuaries. The programme (DMECS) commenced with a teaching seminar held in the University Management Centre in February and sampling has taken place at 26 stations this autumn.

A more basic approach to determining effects of toxic environmental and nutritional contaminants at the subcellular level is to analyse changes in the global expression of genes and proteins in cells (especially the liver) in stressed fish. This is now realisable with the advent of new high throughput technologies such as DNA microarrays and high resolution 2D-electrophoresis. Drs Amer Diab and Ms Vicky Sabine are funded on the EU GENIPOL project (www.genipol.stir.ac.uk) with partners from the Universities of Birmingham, Haifa and Odense to apply these technologies to determine responses in liver cells of flounders exposed to a variety of toxicants. To provide an archive of reference material for the consortium we have sampled livers from flounders artificially reared by Stephanie Chew (MSc student) which we exposed to contaminants in our containment aquarium facilities. These samples have also been used to generate the normalised libraries for the microarray studies. NERC is supporting this project with bioinformatics support through its "Environmental Genomics" programme and Professor George is currently setting up a computing facility for DNA and DNA microarray analysis in support of this and other future projects.

Systems Group

The Systems Group has maintained a diverse and active range of activities throughout the year, both in the UK and internationally, and has continued its very significant inputs into teaching and PhD supervision, with a steadily increasing level of demand for its multidisciplinary PhD programmes, many of which are operated on a 'joint centre' basis, in which fieldwork is carried out in target localities, often overseas. Through the efforts of key staff, contributions from a range of partners, and the enthusiasm of our active group of postgraduate students, we have been able maintain significant outputs in diverse fields. Key staff issues for the year have been Dr David Little's extensive programme of tropical aquaculture work, Dr Janet Brown's development of an applied programme in shellfish culture, Dr Stuart Bunting's increased inputs into technical design and management of temperate and tropical aquaculture systems, Dr Krishen Rana's developing involvement in aquaculture systems in Sub-Saharan Africa and Professor Ross' continuing strategic inputs in conjunction with his role as Dean of the Faculty of Sciences. Paul Bulcock, Polly Douglas, Alison Graham and Anton Imminck have also provided important support. Dr Don MacIntosh's work in collaboration with the University of Aarhus has continued to develop his interests in tropical coastal systems.

As a long-term, and very close collaborator within the Institute, Dr Malcolm Beveridge's departure for FRS Pitlochry has been a significant change, though inputs from his colleagues in the Environment Group, Dr Donald Baird and Dr Trevor Telfer have been valuable and can be expected to develop further. The very active and productive linkage with Professor James Young of the Marketing Department also continue to be an important element in the Group's work. Further linkages are also developing with the Applied Social Science Department and with the Department of Nursing in areas of social research, and community health and nutrition, respectively.

The DFID Aquaculture and Fish Genetics Research Programme (AFGRP), managed by Professor James Muir, continues to be a very important area of interaction for the group, in providing the means to stimulate more strategic thought and practical action, and in supporting the context of broad partnership linkages, both within and outside the University, and between the UK and

developing country partners and institutions. Within and outside the AFGRP, most of our work range continues, although mechanisms have changed. The field co-ordinating role of Dr David Little, key linkages with the Asian Institute of Technology (AIT) and other institutions, and the support of the Environment Group staff, Dr Turnbull, Dr Thompson and Dr Crumlish in the Disease Group, and Professor McAndrew and Dr Penman in the Genetics and Reproduction Group have been very valuable.

The group's themes, developed through Professor Muir's Sustainable Aquaculture Systems work, Professor Ross's GISAP (Geographical Information Systems and Applied Physiology) Group, Dr Brown's Shellfish Group, the Tropical Aquaculture programme co-ordinated by Dr Little, and the Fisheries Sector Marketing and Economics programme run by Professor Young and Professor Muir, continue to shape the group's strategies and development. Stirling Aquaculture also provides links across these areas. Thematic interests remain largely as before, linked as described below:-

- Strategy, planning and development
- Sustainable aquaculture production
- Bioecological bases of production systems
- System and technology design

Strategy, planning and development

A key activity for Professor Muir has been the co-ordination and development of a major multi-donor/government review of the fishery sector in Bangladesh, covering themes of economic performance, livelihoods, social development and environment, institutional frameworks, policy and legal systems. The review, whose outputs are now being produced, covers natural resource systems, social, demographic and economic contexts, capture fisheries, aquaculture, processing and marketing. It provides a comprehensive strategy approach to underscore future private and public sector investment and to guide donor investment in poverty alleviation.

Jeng Shu-ching is completing his PhD studies on development issues underlying innovation in the aquaculture sector in Taiwan, and Nelly Isyagi is now also in the final stages of her work on aquaculture development strategies for small-scale farmers in Uganda. Upcoming work includes Alberto Asiain's study on community development processes in promoting rural



Rice and fish are dietary staples throughout lowland Asia. Increasingly fish like the silver barb pictured here are now cultured. A DFID-AFGRP project worked with the local government institution in southern Laos, the Regional Development Committee (RDC), to improve capacity to spawn and nurse this indigenous species locally.

aquaculture within Mexico, and Adrian Hartley's research on strategic competition issues in the international tilapia market. The group's EU-funded study on organic aquaculture, completed in 2000 continues to generate strong external interest.

The group continued its long-term inputs into FAO aquaculture strategy issues, with Professor Muir's work on sustainability indicators and on land and water use parameters for aquaculture development

Aquaculture production systems

In association with the DFID AFGRP and Natural Resources Systems Programme, with EC funding, and with a range of local partnerships and project linkages, Dr David Little, Dr Stuart Bunting and their regional colleagues have contributed in a range of current activities, including:

- Fish seed quality in Asia: with the Asian Institute of Technology and five national institutions funded by DFID-AFGRP; collaborative research has revealed a range of strategic and technical improvement routes, now being actively taken up by public and private sector hatchery operators. Angus MacNiven, a PhD student based at AIT is completing his work.
- Farmer-managed irrigation systems and aquaculture: research with farmers in water short areas of Karnataka State, India and the dry zone of Sri Lanka funded by DFID-AFGRP, has completed a range of findings and recommendations, now being taken up via the project's research assistant Francis Murray in conjunction with CARE Sri Lanka and the Asian Development Bank.
- Aquaculture integrated within engineer-managed irrigation systems: work with partners in the UK (University of Newcastle) and Sri Lanka (ABC, University of Peradeniya) and India (Tamil Nadu Agricultural University) funded by DFID-KAR has now been completed, and the Stirling field research co-ordinator Lindsay Pollock is completing her PhD and taking the findings forward with key local partners.
- Aquaculture in the peri-urban zone-the Calcutta Wetlands; work by Dr Stuart Bunting, Dr Samantha Punch (Applied Social Sciences) and colleagues, funded by DFID-NRSP, has completed a range of findings and recommendations on livelihood implications of changing resource use in the rapidly expanding city and its adjacent wetlands.
- Recently a further EC-funded INCODEV project has been awarded to David Little and Stuart Bunting to further their work on peri-urban aquatic food production systems with a focus on Southeast Asia.
- Several collaborations are underway with Wageningen University in the Netherlands with EC funding. "Improved resource efficiency in Asian integrated pond-dike systems", is investigating the broader impacts of pond-based fish culture with partners at the Bangladesh Agricultural University, Can Tho University in Vietnam and the Sisaket Agricultural College in Thailand in association with the Fisheries Group within the Department of Animal Science. Another project is underway with Donald Baird and Graeme Taylor in the Environment Group and partners in Alterra, Netherlands and IAV-UCOI University in Portugal assessing the impacts of agrochemicals on aquatic systems in central Thailand and Sri Lanka.

Dr Janet Brown's programme in crustacean production is continuing through a programme of PhD studies, and with STAQ and other field projects. Wara Taparhudee has successfully completed a PhD on the technical, financial and environmental strategies associated with low-water use shrimp farms in Thailand.

Bioecological bases of production systems

Dr Little's study, with Dr Kai Lorenzen of Imperial College, London, on the livelihood impacts of self recruiting species in Asia has developed well, with a range of studies on the role of these species in Indochina, eastern India and Bangladesh. In association with the Environment Group, Dr Beveridge's work on the use of periphyton in aquaculture has been completed in a major workshop in Bangladesh, with a range of practical outputs.

Dr Little has continued his involvement with the British Council Link project with Research Institute Aquaculture 1 (RIA 1) in Bac Nin, near Hanoi, Vietnam focusing on overcoming constraints on the cage culture of grass carp in rivers, and increasing the capacity of RIA1 to appraise developmental constraints and opportunities for poor people in northern Vietnam.

System design

Main areas of work in system design continue together with Stirling Aquaculture, providing practical application and development in the commercial context. The TCS scheme with Luca Montorio, and Alexander Sandison's of Shetland, examining novel water treatment systems, has concluded, with very valuable and widely applicable results in improving the performance of recycle systems. We expect this work to be developed further. Dr Bunting's PhD work on the design of integrated aquatic systems in association with aquaculture has been further developed in our collaboration in an EC funded programme (GENESIS) on ecologically improved recycle aquaculture systems. Bart Vlamincx's work on improved offshore cage designs has been developed with a range of cages now in use.

Geographical information systems

Professor Ross continues as Dean of the Faculty of Natural Sciences, which takes him away from the Institute for the majority of his time. Despite this, he has been able to maintain momentum and development of a growing range of GIS-based planning tools for the aquaculture sector. This year the GIS group saw the successful completion of a number of PhD projects. Oscar Perez-Martinez completed the EC-funded work on modelling island aquaculture using GIS, based in Tenerife. Opportunities and impacts for development of sea bass and bream culture in the islands have been modelled, alongside aesthetic issues such as visual impact which is very important in a tourism-based economy. Eunice Perez-Sanchez recently concluded her GIS-based study of aquaculture development and socio-economic processes in coastal communities of Tabasco, Mexico and Matias del Campo Barquin has finalised his work on economic and GIS-based restocking models for a sea urchin fishery in Chile. Philp Scott, now based in Brazil, has drawn to completion his work on spatial models for bivalve culture developments in Sepetiba bay, west of Rio de Janeiro. High quality publications have resulted from this work, further raising the profile and pre-eminence of the Institute of Aquaculture in this field.

Martin van Brakel is working on GIS-based models for focussing development interventions in areas where poverty is a major factor. Preliminary DFID-funded modelling by Oscar Perez showed that the concept had considerable potential and, with DFID and University support, Martin has been developing a more detailed approach to these problems. Field work in Thailand, Vietnam

and Cambodia is in progress which will allow Martin to focus on more detailed projects, thus enhancing the general regional models which are emerging.

In conjunction with Dr Trevor Telfer, a major step forward has been made in modelling of the fate of particulate wastes from sea cages, using GIS. In a well-executed MSc project, Adam Brooker developed a modular interface within our standard GIS environment for carrying out this modelling, based on substantial datasets and approaches developed at the Institute over a number of years. The approach has substantial benefits over existing models currently in use and we have plans to develop this further over the next few years.

Maria Sefteli developed a superb spatial database and preliminary models for aquaculture development for Michoacan State, Mexico. The resulting MSc thesis gained Maria the award of the Royal Highland and Agricultural Society Silver Medal and the External Examiners prize. The work used multiple data sources and was based on a concatenated image set of 6 Landsat scenes. The database will be used to support our ongoing work with UMSNH in Mexico and to assist the Michoacan state government in preparing their aquaculture development plan, the "Plan Acuicola".

Work with Dr Carlos Martinez's group at the Universidad Michoacana San Nicolas de Hidalgo in Morelia has developed significantly during the year. This British Council supported work is designed to develop an appropriate aquaculture technology for the endangered whitefish *Chirostoma estor estor*, one of a group of atherinid species unique to the Mexican altiplano lakes. These fishes are a major component of artisanal fisheries which have existed for centuries and which have formed the livelihoods of Purepecha and other groups in the area. They are now in decline due to overfishing and environmental change and so an aquaculture technology will be aimed at restocking as well as on-growing, and will address issues including biodiversity, poverty and sustainable livelihoods. Our work is now advancing substantially and Dr Martinez's group has already made a substantial contribution to our knowledge of the species and our ability to culture *Chirostoma* in a closed cycle. Professor Ross, Dr Jauncey, Dr Rana and Dr Malcolm Beveridge were all involved in project work in Mexico during the year, contributing expertise to project design and objectives.

Mangrove research

The Mangrove Group (Dr Macintosh and Elizabeth Ashton) have had a productive year, with the publication of several papers covering various aspects of mangrove biodiversity and the utilisation of mangrove fish and shellfish for aquaculture. Two major studies were completed during 2002, one in Ranong, southern Thailand, the other in the Lower Mekong delta, Vietnam, entitled "The role of mangrove aquatic resources and small scale aquaculture in the livelihood support system of poor coastal settlers in Southeast Asia." Their most significant assignment in 2002 has been a study to produce a Code of Conduct for the Sustainable Management of Mangrove Forest Ecosystems. The World Bank has commissioned the code, which is modelled on the FAO Code of Conduct for Sustainable Fisheries. The first of three regional workshops to consult on the draft code with participating countries was organised by Dr Macintosh and Elizabeth Ashton in Bangkok in October for the Asian region. The Code of Conduct will be presented to the World Bank on 31st March 2003 after a further two workshops early next year covering Africa and Central and South America.

Stirling Aquaculture

Management and longer-term contracts

The Institute's consultancy and project management group, Stirling Aquaculture (STAQ), continues to play an active role in farm management through an offshore cage project with Farmoccean International in Libya. Seabream fry were stocked to nursery cages in August 2001, and two Farmoccean 4500 cages were installed in 2002. Jonathan Grubb and Trevor Meyer provided overall project management and staff training through a series of short-term visits. STAQ has also provided the site management team, involving Patrick Morino (site manager and boat specialist), Orazio Baldacchino (dive instructor) and Bolla Venkataiah (assistant farm manager). Additional short-term inputs have been made by Charles Morino and Louis Baldacchino, whilst Zarko Peric has provided veterinary support and training. Two Libyan staff are also employed and ten counterparts are being trained. Meanwhile in Sicily, our project with Acqua Azzurra was brought to a successful conclusion with Bart Vlaminc taking up a full time appointment with the company.

STAQ continued to act as the UK National Network Leader for the EC-funded Aquaflo project. This disseminates information about aquaculture research projects to producers and other potential users of technology. The group are also partners in an EC funded research and demonstration project "GENESIS", which is investigating various approaches to integrated mariculture in the European context. Stuart Bunting is the main researcher on the project, which also involves Professor Jimmy Young from the Department of Marketing, and partners in Israel, France, Wales and Scotland. Our TCS project with Alexander Sandison and Sons Ltd, was completed with excellent progress made in developing a more reliable and cost-effective recirculation system for the company's salmon hatchery in Shetland.

Consultancy

Several major consultancy projects were carried out during the year. David Currie visited Jamaica at the start of the year, to investigate opportunities for a high health shrimp hatchery project on behalf of the Commonwealth Secretariat. Krishen Rana also made two visits to the island, and to the USA towards the end of the year in a contract for the Inter-American Development Bank funded Agricultural Support Services Project. The main objective was to examine market opportunities for Jamaican produced ornamental fish, and to run a workshop for producers. Jonathan Grubb made the first of two visits to Papua New Guinea to study the trout farming sector in the Highland regions, and its support requirements. This first visit involved extensive travel within PNG over a six week period, meeting farmers, feed producers, processors, education and training establishments and government officers. The project is funded by the Commonwealth Secretariat and involves a second phase in 2002-2003. Our work with the Department of Marketing to review the premium available to the Scottish salmon industry through national and quality labeling was successfully concluded, with guidance provided to SQS (Scottish Quality Salmon) on how the industry might further differentiate their products to maximise available premiums.

Support to the insurance sector continued this year with John Bostock investigating a systems failure at a recycle salmonid hatchery and Trevor Meyer an apparent net failure at a cage site. The consequences of a loss at a salmon restocking hatchery were also investigated with the help of Dr Colin Bull of the Forth Fisheries Foundation. Paul Bulcock worked on a number of consultancies including a market opportunity study for a novel

design microscreen filter, opportunities for aquaculture investment in Ireland and research to support an engineering company with product development. John Bostock worked with Argyll and Islands Enterprise and Business Gateway to help with the evaluation and monitoring of small business grant projects in the aquaculture sector. Advice was provided in systems design to projects in Brunei and South Africa and a special short-course was arranged for a group of visitors from China. Research inputs were also made to an FAO review of land and water use in aquaculture, and support provided to Professor Muir's Sector Review in Bangladesh.

Aquaculture Technology Centre

The development of the Aquaculture Technology Centre (ATC) as a broader grouping of commercial services within the Institute of Aquaculture was pursued during the year, especially through an "Open Doors" event where local businesses were invited to a reception and tour of the Institute. A poster competition for PhD students was run as part of the event, won by Mark Freeman from the Parasitology Group, and a new brochure and web site (www.atc.stir.ac.uk) was launched. The ATC was also promoted at the Aquaculture International 2002 event in Glasgow, and the World Aquaculture Conference and Exhibition in Beijing. In a further development, BBSRC funding support was obtained for the development of three short training courses for the aquaculture industry, to run under the auspices of the ATC in collaboration with the University of Glasgow.

Staff

There have been a number of staff changes during the year. Polly Douglas joined in September to act as dissemination officer for the DFID Aquaculture and Fish Genetics Research Programme (see Systems Group report) and has taken on many of the responsibilities for the Aquaflow project. Alison Graham joined in June after completing the MSc Aquaculture course, replacing Paul Bulcock, who accepted a post with the STREAM project in Thailand and transferred in May. Trevor Meyer also took the opportunity to move to a tropical marine fish culture project in Indonesia in July. Trevor and Bart Vlamincck (now with Acqua Azzurra) remain Associate Consultants to STAQ.

Future initiatives

Looking forward, contract negotiations are underway with the EC to create a supporting network for innovation and technology transfer in European aquaculture. Assuming satisfactory finalisation of the contract, STAQ will act as project coordinator for this exciting initiative, facilitating the development of a number of new services that should enhance our already varied mix of consultancy, training and project support activities.

External Facilities

Howietoun, Buckieburn Freshwater Research Unit, Machrihanish Marine Environmental Research Laboratory and Machrihanish Marine Farm (MMF) have had a busy year with excellent results.

Howietoun

Smolt production at Howietoun continue to expand with a 10% increase in production to 580,000. This is expected to increase by a further 10% in 2003. Twenty eight-day survivals were again excellent but IPN losses 6-8 weeks after delivery mirrored an increasing trend elsewhere in the salmon industry. IPN losses appear to be stock related and we have taken steps to avoid fish of similar genetic origins in the future.

The loss of malachite green as a fungal treatment in freshwater is a serious blow to the salmon smolt industry as licensed replacements are expensive and not as efficacious. We are developing new methods for reducing stress at vaccination, as this appears to predispose the pre-smolts to fungal infections. It is likely that the lack of an effective cure for fungal infections will seriously reduce the expansion of the smolt industry, and subsequently the salmon on-growing industry for some time to come. The main problem appears to be in freshwater loch sites but fortunately only 25% of our production is in such sites with the majority being from tank production which makes fungal control easier and cheaper. In addition we are very fortunate that the smolt sites at Howietoun and Buckieburn appear to have very low fungal spore counts which have obviated the need for treatments in the past.

The salmon on-growing industry has suffered very low market prices over the last twelve months but there are now welcome signs that prices are rising and indications for future prices are good. The globalisation of salmon farming continues and it is likely that there will be more consolidation in the future as the number of independent salmon farmers declines.

A Ministerial Working Group of the Scottish Executive is in the late stages of preparation of a document which will map out the future of aquaculture in Scotland. We hope this will go some way to highlighting the value and importance of aquaculture to the fragile Highland economy and indeed to that of Scotland itself. The Institute has had extensive involvement in this process and it is expected that the document will be published by the end of the year. We hope that this exercise will result in more positive support from Government for aquaculture with consequent opportunities for our operations.

Brown trout sales again have been difficult this year with the hangover effects of foot and mouth reducing angling club budgets. There are now signs that foot and mouth is behind us with strong interest in sales for 2002-2003. Our customer base is large and loyal and we do not appear to have suffered any long term damage, however, there is concern in the angling industry that young people in particular, are turning away from country pursuits. At Howietoun we are actively encouraging young anglers with initiatives through the Scottish National Anglers Association and Scottish Water.

Developments on trout restocking restrictions in England are causing some concern. There are moves to control restocking and promote "wild strains" of discrete genetic origin. This has not yet been suggested in Scotland, but it may come. In the meantime English restockers are looking enviously at the Scottish market. We could contract grow "discrete genetic strains" at Howietoun for clients, but there are some disease risks in bringing in eggs from different sources. Howietoun has restocked virtually all of the accessible trout waters in Scotland over the last 120 years and this has been well documented and archived. It is thus unlikely that there are many discrete wild strains in Scotland. This database may prove very useful in the future if restrictions reach Scotland.

Buckieburn Freshwater Research Unit

Buckieburn has had another successful year with an increasing number of contract research trials completed. The most significant was a malachite green depuration trial carried out on behalf of the salmon industry. This clearly showed the very long depletion time for the malachite metabolite, leucomalachite. The trial was carried out to GLP standard in conjunction with Machrihanish, under the supervision of Bill Roy, and has set the

scene for similar studies in the future. We have also carried out toxicology studies on new sources of fishmeal for a major multinational company.

The Institute Reproduction and Genetics Group, under the supervision of Professor Bromage, use the facilities at Buckieburn extensively for trials on daylength control of spawning and smolting and the DEFRA/BTA project on stocking density and welfare is continuing to provide very interesting and useful results.

The new office and laboratory at Buckieburn is nearing completion and will provide excellent facilities for Buckieburn staff and visiting staff and students. In addition to an office and meeting room there is a changing area and laboratory. This is a much needed facility and has been provided from central university funds in addition to proceeds from the sale of Stirling Aquatech.

Machrihanish

Machrihanish has had another productive and profitable year with the focus of work starting to move from salmon to new species, primarily cod. With the building of a new cod hatchery Machrihanish will become the major centre for cod research in Britain.

Research on salmon is still of major importance, particularly in sea lice control. We are investigating the efficacy of a very promising new candidate for sea lice control and completed trials suggest that this product, if taken to license, will significantly increase the array of products available to the salmon industry to combat sea lice. The techniques developed with sea lice products in collaboration with Professor Sommerville and the Parasitology Group have been used in field trials to control *Argulus* in trout populations in still water fisheries in England. This is an emerging and serious condition in English fisheries and this work is thus timely. We have also carried out preliminary trials to control *Lernanthropus kroyeri* on sea bream in Greece and Turkey.

Photoperiod work on cod is continuing and this major trial is providing essential information for the new cod industry. Farmed cod mature after their second winter before it is economically viable to harvest them. This work has shown that maturation can be delayed by up to six months which will allow the cod to reach 3 kg plus. The trial, which is part of Andrew Davies' Ph.D,

is also being paralleled in cages at Lakeland Marine's project Craignish site, our partner in MMF. The 60,000 cod put into this site last year have grown very well but there have been continued problems with vibrios. We are midway through a trial with Aquaculture Vaccines Ltd aimed at producing a cod specific vibrio vaccine which may solve the problem.

In conjunction with Port Erin, Isle of Man we have produced 30,000 cod juveniles at Machrihanish this year and these will be moved to Wester Ross and Shetland in early December. The demand for juveniles is great but there are difficulties in obtaining sites for cod. We have been involved with an application from Lakeland Marine for the first large scale cod site in Scotland and this has now been awarded, 18 months after the application was submitted. With the problems in the wild cod fishery there are tremendous opportunities emerging for cod farming but help and support will be required from Government and other agencies to make this a commercial reality.

Now that the hatchery at MMF is established and producing vast quantities of live feed for larval and young fish we will attempt to pioneer the development of other new species such as hake in the old lifeboat station.

A number of trials have been carried out in the isolation unit testing the efficacy and safety of new antibiotics primarily against *Vibrio* sp and we hope to use the unit to carry out a project on amoebae in conjunction with Institute colleagues under the Institutes EU funded Improving Access to Infrastructures programme. Amoebae are a significant problem for salmon in Ireland and also in Mediterranean species.

Machrihanish Marine Farm Ltd

Construction of the new hatchery commenced in autumn 2001 and the first phase was commissioned in August 2002. The building and plant is operating very well and water quality is exceptional. The first eggs were introduced in mid August and a pilot crop of around 10,000 juveniles was produced to test out the systems and live feed production. At the time of writing the first commercial crop is being stocked from eggs from our broodstock and these fish should be available for sale in spring of 2003. Our target is 250,000 juveniles from this first crop. Interest in cod juveniles is very high and we anticipate selling 50% of the production as 1-2 gm juveniles and the other 50% as 50-100 gm codling.

We are currently initiating phase two of the project, which is for growout from 1 gm to 50-100gm. This phase will use throughflow rather than recirculation technology as trials have shown that at the very high growth rate exhibited by cod, carbon dioxide production can cause significant problems for juveniles. Stripping of CO₂ from recirculation facilities is not as easy as in a throughflow system so we have opted for the latter, safer, system. The production from both phases one and two is expected to be in the region of 1.2 million cod juveniles per annum. Phase two should be completed for an official Royal opening in May 2003.

Cooperation with our partner in the joint venture, Lakeland Smolts Ltd, has been excellent. A sister company, Grieg Marine Farm in Norway, at an identical stage of development as MMF has allowed very beneficial technology transfer between both organizations.

Dr Robertson is an SQS Council Member and is Chairman of the Freshwater Sectoral Committee, a member of the Technical Committee and Fish Health Working Group and is also Director of the British Marine Finfish Association.



Continuous algal production system in the algal room at the new Machrihanish Marine Farm Ltd cod hatchery.

Appendix I

Advisory Committee

Professor C Bell,	Principal of University and Chairman
Professor I D Aitken, OBE	Scientific Director, Edinburgh Centre for Rural Research
Professor Sir James Armour	Vice President of Royal Society of Edinburgh
Mr K Clarke	University Secretary (<i>ex officio</i>)
Mr H M Currie	Managing Director, Lithgows Limited, Chairman CBI Scotland
Dr E Edwards, OBE	Vice President, Shellfish Association of Great Britain
Dr Ph. Ferlin	Director, Institut National de la Recherche Agronomique
Professor R H Richards	Director of Institute (<i>ex officio</i>)
Professor L G Ross	Dean of Faculty of Natural Sciences (<i>ex officio</i>)
Dr P Sorgeloos	Artemia Reference Centre, University of Ghent
Dr J Tarbit OBE	Former Senior Fisheries Adviser, DFID
Professor P N Wilson, CBE	Professor Emeritus, University of Edinburgh
Mr N Yonge	British Trout Association

Appendix II

Staff List (at 1/10/2002)

Director of Institute and RMB Professor of Aquatic Veterinary Studies	Randolph H Richards MA, VetMB, PhD, MRCVS, FIBiol, FRSM, ARAGS	Chief Technician (Disease) Chief Technician (EM) Chief Technician (Nutrition) Chief Technician (Genetics) Chief Technician (Genetics) Chief Technician (Engineering) Chief Technician (GLP/Genetics) Chief Technician (Fish Husbandry) Chief Technician (Purchasing/Stores) Chief Technician (Environment) Chief Technician (Electronics)	Stuart D Millar CBIol, MIBiol Linton Brown James Dick Cathryn Dickson BSc, MSc Ann Gilmour Brian Howie Stephen Powell BSc Keith Ranson BSc Elizabeth Stenhouse William Struthers William Thomson
Deputy Director	Rodney Wootten BSc, BA, PhD		
Assistant Director, Research and Professor of Fish Reproduction	Niall Bromage BSc, PhD		
Assistant Director and Professor of Aquaculture Development	James F Muir BSc, PhD		
Professor of Aquatic Molecular Genetics	Alan J Teale, BA, MA, VetMB, MSc PhD, MRCVS	Senior Technician (Bacteriology) Senior Technician (Teaching) Senior Technician (Histopathology) Senior Technician (Purchasing/Stores) Senior Technician (Nutrition) Senior Technician (Virology) Senior Technician (Nutrition) Senior Technician (Nutrition) Senior Technician (Vaccine Unit) Senior Technician (Virology) Senior Technician (Nutrition)	Gillian Dreckzkowski BSc Iain Elliot Debbie Faichney BSc Charlie Harrower Jim Henderson BSc, PhD Jacquie Ireland BSc Liz Mackinlay BSc, MPhil Fiona McGhee BSc Hilary McEwan Fiona Muir BSc Irene Younger
Professor of Diagnostic Fish Pathology and Microbiology	Hugh W Ferguson, BVMS, PhD, DipACVP, MRCVS, FRCPath		
Professor of Aquatic Physiology	Lindsay G Ross BSc, PhD		
Professor of Aquatic Parasitology	Christina Sommerville BA, PhD		
Professor of Aquaculture Genetics	Brendan J McAndrew BSc, PhD		
Professor of Environmental Toxicology	Stephen G George BSc, PhD, MPhil	Technician (Fish Husbandry) Technician (Fish Husbandry) Technician (Parasitology) Technician (Fish Husbandry) Technician (Environment) Technician (Purchasing/Stores) Technician (Histopathology) Technician (Environment) Technician (Environment) Technician (Nutrition) Technician (Genetics) Technician (Vaccine Unit)	Robert Aitken Niall Auchinachie BSc, MSc Denny Conway BSc William Hamilton Anne Hammond BSc Jane Lewis Maureen Menzies Kirsty Pollock Nora Pollock BA Alan Porter Stephen Powell BSc Karen Sneddon BSc, MSc
Reader	Sandra Adams BSc, PhD		
Reader	Michael V Bell BSc, PhD		
Professor Emeritus	Allen J Matty BSc, PhD, DSc	Departmental Assistant Departmental Secretary Secretary Journals Secretary Financial Coordinator	Beatrice Campbell BA Hazel Gentles Lynn More Christine Kerr Melanie Cruickshank BSc
Professor Emeritus	Ronald J Roberts BVMS, PhD, FRCPath., FRCVS, FIBiol, FRSE		
Professor Emeritus	John R Sargent BSc, PhD, FIBiol, FRSE		
Honorary Professor (Marine Fish)	John H S Blaxter MA, DSc, Univ, FRSE		
Honorary Professor	David Mackay Ch.Biol, FIBiol, FIWEM, FIMgt, MIFM		
Senior Lecturer	J Gordon Bell BSc, PhD		
Senior Lecturer	D J Macintosh BSc, PhD		
Senior Lecturer	Douglas R Tocher BSc, PhD		
Senior Lecturer	Donald J Baird BSc, PhD		
Senior Lecturer	Kim Jauncey BSc, PhD	Stirling Aquaculture (Consultancy Group) Manager	John Bostock BSc, MSc
Lecturer and Course Director MSc Aquatic Pathobiology/Vet Studies	Jimmy Turnbull BVMS, MSc, PhD, MRCVS	Project Assistant (Information and Dissemination)	Polly Douglas BSc
Lecturer and Course Director MSc Aquaculture	Trevor C Telfer BSc, PhD, CBIol, MIBiol, MIEEM	Project Assistant Project Assistant Project Assistant	Penelope Beaton BSc, MSc Adam Brooker BSc, MSc Alison Graham BSc, MSc
Lecturer	Nigel Willby, BSc, PhD		
Research Lecturer	James E Bron BSc, MSc, PhD	Project Manager (Libya) and Associate Senior Consultant Site Manager (Libya) Farm Supervisor (Libya) Dive Instructor and Assistant Supervisor (Libya)	Jonathan Grubb MSc Patrick Morino Bolla Venkatayah Orazio Baldacchino
Research Lecturer	Janet H Brown BSc., PhD		
Research Lecturer	David Penman BSc, PhD		
Research Lecturer	Krishen Rana BSc, PhD		
Research Fellow	Elizabeth Ashton BSc, D.Phil	Associate Senior Consultant Associate Senior Consultant Associate Senior Consultant Associate Senior Consultant Associate Senior Consultant	David Currie BSc, MSc Zarko Peric MVS, DVM Trevor Meyer BSc, MSc David Scott MSc Bart Vlamincik BSc, MSc
Research Fellow	Kerry Bartie BSc, PhD		
Research Fellow	Margaret Cairney BSc, PhD		
Research Fellow	Anne Conrad BSc, MSc, PhD		
Research Fellow	Margaret Crumlish BSc, MSc, PhD		
Research Fellow	Tariq Ezaz BSc, PhD		
Research Fellow	Simon Harvey BSc, PhD		
Research Fellow	Michael Leaver BSc, PhD		
Research Fellow	David D Little BSc, MSc, PhD	External Facilities External Facilities Director	D A Robertson BSc, PhD
Research Fellow	David Morris BSc, PhD		
Research Fellow	Victoria Sabine BSc, MSc		
Research Fellow	Andrew P Shinn BSc, PhD		
Research Fellow	William Starkey BSc, PhD	Howietoun Fish Farm General Manager Fishery Manager Foreman Senior Stockworker Stockworkers	Robert J A Murray BSc Iain J Semple BSc James Rae Kevin Smith Chris Thornton Colin Forrest
Research Fellow	Janet Stone MSc, MIBiol, FIMLS		
Research Fellow	John Taggart BSc, PhD		
Research Fellow	Kim D Thompson BSc, MSc, PhD		
Research Fellow	Xiaozhong Zheng BSc, PhD		
Project Officer	Stuart Bell BSc, MSc, PhD	Secretary Cleaner	Grace Smith Rhona Smith
Project Officer	Garnet Hooper BSc, MSc, PhD		
Research Assistant	Amer Diab BSc, MSc		
Research Assistant	Stuart Bunting BSc, MSc, PhD	Buckieburn Foreman Stockworker	Alastair McPhee, BSc John Gardiner
Research Assistant	Anton Imnink BSc, MSc		
Research Assistant	Ben North BSc, MSc		
Research Assistant	Graham Taylor BSc, MSc		
Teaching Company Associate	Anu Frank-Lawale BSc, MSc	Dunblane Foreman	J Allan Chalmers
Veterinary Clinical Officer	Richard Collins BVMS, MSc, MRCVS	Machrihanish Marine Environmental Research Laboratory Manager Site Engineer Foreman Technician Contract Researcher Research Fellow Stockworker Cleaner	William Roy BSc, PhD Simon Barnett Chessor Matthew BSc Sally Boyd BSc Jocelyn Richard BSc, PhD Janet Stone MSc, MIBiol, FIMLS Keith Mathieson Elizabeth Irwin
Honorary Lecturers	Gordon Rae BSc John Wickens BSc F J Wrona BSc, PhD		
Safety Officer	Michael V Bell BSc, PhD		

Appendix III

PhD Students 2001/2002

Mr I Al Mohsen, B.Sc., M.Sc. Saudi Arabia, (Saudi Arabian Government)

Ms E Alorend, B.Sc., M.Sc., France, (BMFA, NUTRECO)

Mr A Asiain Hoyos, B.Sc., M.Sc., Mexico, (CONACyT)

Ms B Basso Mercado, M.Sc., Mexico, (CONACyT)

Mr A Bell, B.Sc., M.Sc., UK, (LINK Aqua)

Mr I K Berrill, B.Sc., M.Sc., UK, (NERC CASE)

Ms C Boonphakdee, B.Sc., M.Sc., Thailand, (Government Scholarship)

Mr J Botero, M.Sc., Colombia, (Colombian Government/INPA)

Mr I Brierley, B.Sc., M.Sc., UK, (EU)

Mr C Brown, B.Sc., M.Sc., UK, (Alkioni Fish Farms)

Mr S Bunting, B.Sc., UK, (University of Stirling Studentship)

Mr A Campos Mendoza, B.Sc., Mexico, (CONACyT)

Mr R Campos-Ramos, B.Sc., M.Sc., Mexico, (CONACyT)

Ms P Carter, B.Sc., UK, (BBSRC CASE)

Mr D Chan, B.Sc., M.Sc., UK, (BBSRC/Silsoe)

Mr J D Chara, B.Sc., M.Sc., Colombia, (COLIENCIAS)

Mr P Christofilogiannis, B.Sc., M.Sc., Greece, (Greek Government)

Mr R Corner, B.Sc., UK, (NERC CASE)

Ms J Costa, B.Sc., Portugal, (Foundation of Science and Technology, Portugal)

Ms C Crichton, B.Sc., Canada, (EC)

Mr S Cross, B.Sc., M.Sc., Canada, (Private)

Mr A Davie, B.Sc., M.Sc., UK, (NERC)

Mr L M Del Campo Barquin, B.Sc, Chile, (Private Funds)

Mr T J Dixon, B.Sc., UK, (NERC)

Mr M T Ezaz, B.Sc., M.Sc., Bangladesh, (Private Funds)

Mr A Faruk-Ul-Islam, B. Sc., M.Sc, Bangladesh, (DIFD-AFGRP and SUFER)

Mr G Faruque, B. Sc., M.Sc, Bangladesh, (British Council)

Ms M Felsing, B.Sc., M.Sc, Denmark (Faculty of Natural Science Studentship)

Mr J Fonseca Madrigal, B.Sc., B.Tech MLS, Mexico, (CONACyT)

Mr A Frank Lawale, B. Sc., M.Sc, UK, (TCS Research Grant/Staff Development)

Mr M A Freeman, B. Sc, UK, (BBSRC)

Mr M Fuentes, B.Sc., M.Sc., Ecuador, (Chilean Government)

Ms W Futter, B.Sc., M.Sc., UK, (BBSRC CASE/BTA)

Mr K A Glover, B.Sc., UK, (Norwegian Research Council/Statdraft)

Mr A Gomna, B. ED., M. Tech, Nigeria, (Government scholarship)

Ms J E Good, B.Sc., UK, (EWOS)

Ms D A Guerrero Tortolero, M.Sc., Mexico, (CONACyT)

Mr A Hajizadeh Kapateh, B. Sc., M.Sc, Iran, (Iranian Government)

Ms L C Halfyard, B.Sc., M.Sc., B.Ed., Canada, (Private)

Mr A Hamilton, B.Sc., M.Sc., UK, (BBSRC)

Mr A Hartley Alcocer, B. Sc., M.Sc, Mexico, (CONACyT)

Mr R B Hassan, B.Sc., M.Phil., Malaysia, (Government of Malaysia)

Ms N Hastings, B.Sc., UK, (NERC)

Ms A Holzer, B.Sc., M.Sc., Austria, (Austrian Academy of Sciences)

Mr F Ibrahim, B. Sc, Oman, (Private Funds)

Ms A N Isyagi, M.Sc., B.V.M., Uganda, (World Bank)

Mr S C Jeng, B.Sc., M.Sc., Taiwan, (Taiwan Government)

Mr I Karapanagiotidis, B.Sc, M.Sc., Greece

Mr M Karim, B. Sc., M.Sc, Bangladesh, (World Bank)

Mr M Khan, B.Sc., M.Sc., Bangladesh, (British Council)

Mr P N Lewis, B.Sc., M.Sc., UK, (University of Stirling Studentship)

Mr A Macniven, B.Sc., M.Sc., UK, (DFID)

Mr C G Mahika, M.Phil., B.Sc., Tanzania, (World Bank)

Ms L Marshall, B.Sc., M.Sc., UK, (AVL and Biomar)

Mr M F Matori, D.V.M., Malaysia, (University Putra, Malaysia)

Mr C Mazorra De Quero, Lic., Spain, (Technology Foresight)

Ms U McCarthy, B. Sc., M.Sc, UK, (Faculty Studentship/AVL)

Mr C McGurk, BVMS., MSc, UK, (NERC)

Mr M H Medina Ginepro, B.Sc., Chile, (Chilean Government)

Mr G Milwain, B. Sc., M.Sc, UK, (DFID)

Mr L Montorio, B.Sc., Italy, (Private, Alex Sandison and Sons Ltd)

Mr E Morales, B. Sc, Philippines, (DFID/ARP)

Ms A L Morgan, B.Sc., M.Sc., UK, (NERC CASE)

Mr D C Morris, B.Sc., UK, (NERC)

Mr F Murray, B.Sc., M.Sc., UK, (DFID)

Ms N Musa, B. Sc., M.Sc, Malaysia, (Malaysian Government)

Mr J P Neary, B.Sc., M.Sc., Canada, (University Studentship)

Mr D D Nhampulo, B.Sc., Mozambique, (Educational Trust/British Council)

Mr M B Noordin, B.Sc., M.Sc., Malaysia, (Malaysian Government)

Mr B P North, B.Sc., UK, (DEFRA/Private)

Mr O Perez Martinez, B.Sc., M.Sc., Spain, (Marie Curie Fellowship)

Ms E Perez Sanchez, B.Sc., M.Sc., Mexico, (BC/CONACyT)

Ms N Petchsupa, B.Sc., M.Sc., Thailand, (Thai Government)

Ms L Pollock, B. Sc, UK, (DFID)

Mr R A Retamales, M.Sc., Chile, (ORS)

Mr D Riddell, B.Sc., M.Sc., UK, (NERC CASE)

Mr N Sanchez-Perez, B.Sc., M.Sc., Mexico, (CONACyT)

Ms S Sayeed, B. Sc., M.Sc, Bangladesh, (Commonwealth Scholarship)

Mr P C Scott, B.Sc., M.Sc., Brazil, (Brazilian Government)

Ms R Sharif, B.Sc., M.Sc., UK, (EWOS)

Ms N Sheriff, M.Phil, B.Sc., UK, (University Studentship)

Mr W Taparhudee, B.Sc., M.Sc., Thailand, (Royal Thai Government)

Mr M Tayamen, B.Sc., M.Sc, Philippines, (AADCP)

Mr J F Taylor, B.Sc., M.Sc., UK, (Commercial Fish Farm)

Mr N Taylor, B.Sc., UK, (Environmental Agency and BTA)

Ms A B Treuner, Diplom Biologie, Germany, (DAAD/EU Project TROCA-WET)

Ms E Turgut, B.Sc., M.Sc, Turkey, (Gaziosmanpasa University)

Mr D Turongruang, M. A, Thailand, (EC-INCODEV Project)

Mr J P Ureta Schmidt, B.Sc., Chile, (Private)

Mr M L Van Brakel, M.Sc, Netherlands, (University/DFID)

Mr G Von Hoegen, B. Sc., M.Sc, Germany, (Private)

Mr M T Wayland, B.Sc., UK, (NERC CASE/Nat. History Museum)

Mr P M Williams, B. Sc, UK, (NERC)

Mr C Yanes-Roca, B. Sc, Spain, (Private)

Mr S Yuksele, B.Sc., Turkey, (Turkish Government and Aquaculture Vaccines)

MSc Aquaculture 2001/2002

Ms P. Beaton, UK (Private)

Ms M. Bril, Spain (Private)

Mr A.J. Brooker, UK (BBSRC)

Mr S.P. Camp, UK (Private)

Mr A. Chantzopoulos, Greece (Private)

Mr W.C.M. Chow, Singapore (Ministry of National Development, Singapore)

Mr N. Clarke, UK (Fishmongers)

Ms M.D. Gavino-Nadal, Spain (Private)

Ms A. Graham, UK (SAAS)

Mr M.P. Heeps, UK (Private)

Mr R.A. Henderson, UK (SAAS)

Ms C. Lecouffe, France (Ministry of Agriculture)

Ms F. Manjji, Kenya (Private)

Mr A.B. Margolis, Swiss/Mexico (Private)

Mr G. McKinley, UK (BBSRC)

Mr J.C. Mota Velasco Gallardo, Mexico (CONACyT)

Mr M. Perrakis, Greece (L.E.A.)

Mr P. Reynolds, UK (SAAS)

Ms M.M. Saavedra, Portugal (Rotary Club Foundation Scholarship)

Ms J. Sawanboonchun, Thailand (Private)

Ms M. Seftell, Greece (Private)

Mr D. Whitaker, UK (Private)

Mr L. Wilkinson, UK (Private)

MSc by Research

Mr Y Al-Rashada, B.Sc, Saudi Arabia, (Saudi Arabian Government)

Mr E Gozogozoglu, B.Sc., Turkey, (Food and Agriculture International)

Mr R Serwata, Diploma in Animal Technology, UK (Private)

Mr J Vargas-Vazquez, M.Sc, Mexico, (CONACyT)

Appendix IV

MSc Aquaculture Theses 2001-2002

- Beaton P. Aquatic self-recruiting species in rural livelihoods, Cambodia
- Bril M. Effect of rotifer enrichment diets on survival and growth performance of pez blanco (*Chirostoma estor estor*) larvae
- Brooker A.J. Development and integration of waste dispersion models for cage aquaculture within the GIS framework
- Camp S.P. Investigation into the existence of putative sex chromosomes in the Atlantic halibut, *Hippoglossus hippoglossus*, by molecular, synaptonemal complex and mitotic chromosome analysis
- Chantzopoulos A. Egg and larval quality of the Atlantic salmon, *Salmo salar*: effects of photoperiod, temperature and vaccination
- Chow W.C.M. Information technology needs of a halibut hatchery: a case study
- Clarke N. The effects of conjugated linoleic acid (CLA) on lipid metabolism and immune function in juvenile rainbow trout (*Oncorhynchus mykiss*)
- Gavino-Nadal M.D. Evaluation of the ability of a new aquaculture species (*Dentex dentex*) to degrade various dietary proteins using *in vitro* technique
- Graham A. The effects of dietary chromium on stress in pez blanco (*Chirostoma estor estor* L)
- Heeps M.P. The effects of different methods of disinfection on haddock (*Melanogrammus aeglefinus*) egg survival and subsequent larval performance
- Henderson R.A. The use of degenerate PCR for the isolation of selected genes in larvae of the salmon louse *Lepeophtheirus salmonis* (Krøyer, 1837)
- Lecouffe C. The role of mud crab farming (*Scylla paramamosain* Estapampador, 1949) in coastal resettlement areas of Vinh Chau district, lower Mekong delta, Vietnam.
- Manji F. Development and characterisation of monoclonal antibodies against sturgeon Igm
- Margolis A.B. Evaluation of the water disinfection capacity of the ionic accelerator filter in comparison with the effectiveness of ultraviolet irradiation and ozone systems
- McKinley G. Detection of aquatic *Mycobacterium* spp. in ornamental fish using non-destructive sampling techniques
- Mota Velasco Gallardo J.C. Sex identification in *Oreochromis niloticus* L. by sex-linked DNA markers and progeny-testing
- Perrakis M. Identification, distribution and utilisation of tilapia spp. of the Pongolo floodplain, South Africa.
- Reynolds P. Environmental benefits of interactive feedback feeding systems in marine cage culture.
- Saavedra M.M. Effects of methyl parathion on the heartbeat and gut movements of the white shrimp, *Litopenaeus vannamei* (Boone, 1931)
- Sawanboonchun J. The effect of different live feed commercial enrichments on cod (*Gadus morhua* L.) and haddock (*Melanogrammus aeglefinus*) larval performance
- Sefteli M. The development of a preliminary GIS model for evaluation of inland aquaculture in Michoacan, Mexico
- Whitaker D. An investigation into the early life history of Atlantic cod (*Gadus morhua* L.) under hatchery conditions.
- Wilkinson L.A. Characterisation and application of monoclonal antibodies raised against *Flavobacterium psychrophilum*, the causative agent of rainbow trout fry syndrome.

PhD Theses 2001 – 2002

- Banks B.A. Genetic characterisation of populations of the ectoparasitic copepod *Lepeophtheirus salmonis* (Kroyer 1837) in Scotland
- Bell S. Exocrine glands of the caligid copepod *Lepeophtheirus salmonis* (Kroyer 1837)
- Bunting S.W. A design and management approach for horizontally integrated aquaculture systems
- Butler R. *In vitro* modelling of the immunological interactions between the salmon louse, *L. salmonis*, and the Atlantic salmon *Salmo salar* (L).
- Campos Ramos R. The synaptonemal complex and analysis of sex chromosomes in the genus *Oreochromis*
- Dickson C. Development of a stereo imaging system for estimation of biomass of free-swimming fish
- Douglas P.J. Studies on *Entobdella hippoglossi* (Muller, 1776) (Monogenea) and *Lepeophtheirus hippoglossi* (Krøyer, 1837) (Copepoda); ectoparasites of Atlantic halibut (*Hippoglossus hippoglossus* L., 1758)
- Ezaz M.T. Analysis of sex determination in Nile tilapia (*Oreochromis niloticus* L.): a molecular genetics approach
- Lewis P.N. The morphology and function of the peritoneum in lower vertebrates with special reference to teleosts
- Mazorra de Quero C. The management of broodstock Atlantic halibut (*Hippoglossus hippoglossus*) and the influence of nutrition, holding conditions and hormonal manipulation of spawning on gamete quality
- McWilliam R.A. Toxic anorexia in *Daphnia magna* Straus as an *in situ* indicator of the ecological impacts of pollutants
- Mahika C.G. A culture-based conservation strategy for the endangered tilapia *Oreochromis variabilis* (Boulenger, 1906) in the Lake Victoria Basin – Tanzania
- Miles D. Studies on host responses to *Aphanomyces invadens*
- Perez-Martinez O. GIS-based models for optimisation of marine cage aquaculture in Tenerife, Canary Islands
- Perez-Sanchez E. Coastal aquaculture and resources management in the Mecocan estuary, Tabasco, Mexico
- Petchsupa N. Studies on proliferative kidney disease with particular reference to vaccine development.
- Salam A. The potential of geographical information system based modelling for aquaculture development and management in south western Bangladesh
- Turgut E. Characterisation and detection of *Renibacterium salmoninarum* cultured *in vivo* and *in vitro*
- Zulfikar Ali MD. Dietary protein and energy interactions in African catfish *Clarias gariepinus* (Burchell, 1822)

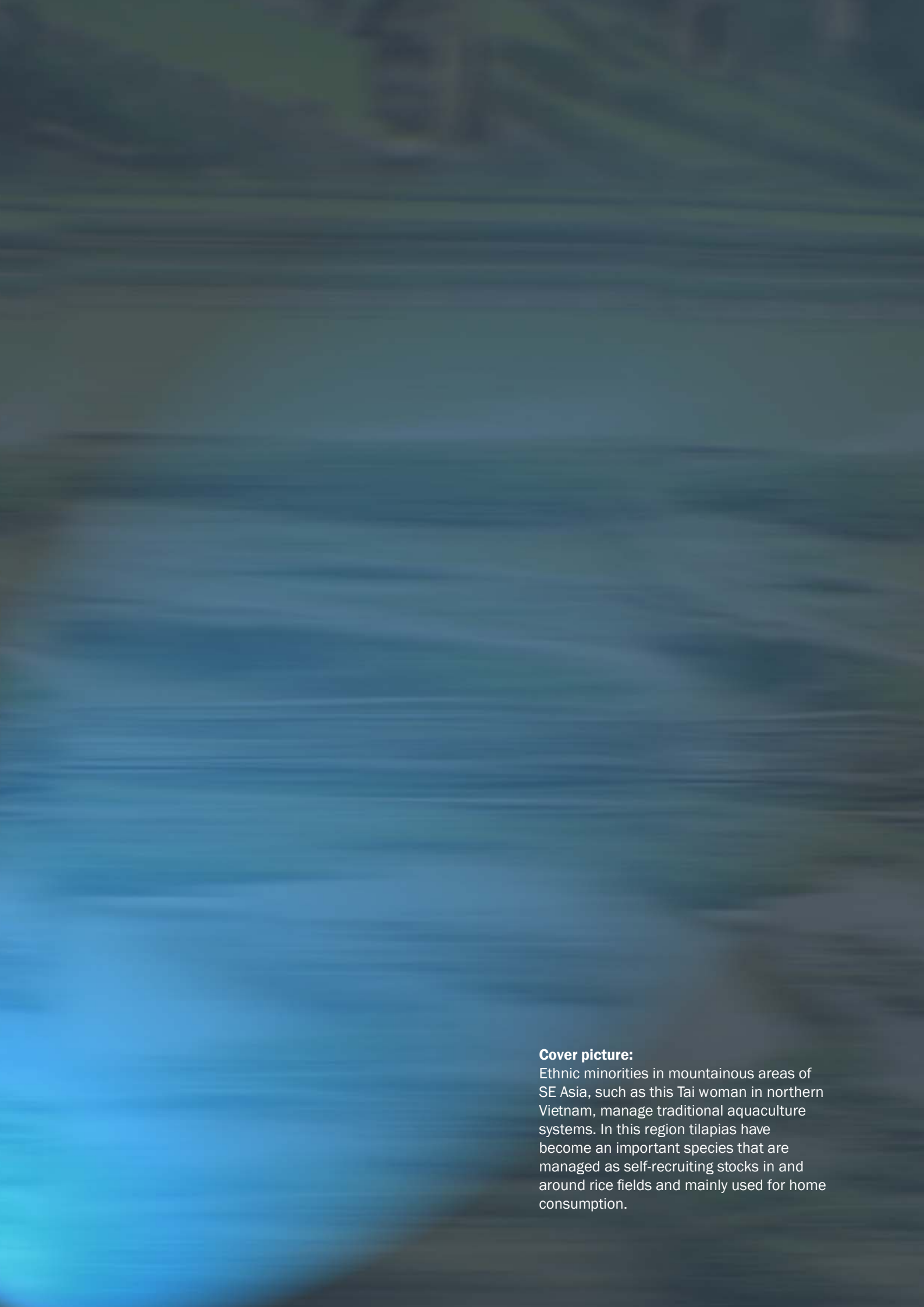
Appendix V

Publications

- Alday-Sanz, V.M., Roque, A. and Turnbull, J.F. (2002) Studies on the pathogenesis of *Vibrio* sp. infection in *Penaeus monodon* Fabricius. *Diseases of Aquatic Organisms* 48, 91-99.
- Ashton, E.C. (2002) Mangrove sesamid crab feeding experiments in peninsular Malaysia. *Journal of Experimental Marine Biology and Ecology* 273, 97-119.
- Ashton, E.C. and Macintosh, D.J. (2002) Preliminary assessment of the plant diversity and community ecology of the Sematan mangrove forest, Sarawak, Malaysia. *Forest Ecology and Management* 166, 111-129.
- Asturiano, J.F., Sorbera, L.A., Carrillo, M., Zanuy, S., Ramos, J., Navarro, J.C. and Bromage, N. (2001) Reproductive performance in male European sea bass (*Dicentrarchus labrax*, L.) fed two PUFA-enriched experimental diets: a comparison with males fed a wet diet. *Aquaculture* 194, 173-190.
- Bakopoulos, V., Adams, A., Galeotti, M. and Dimitriadis, G.J. (2001) *In vitro* growth inhibition studies of *Photobacterium damsela* subspecies *piscicida*, using various immunological probes. *Bulletin of the European Association of Fish Pathologists* 20, 237-243.
- Barata, C., Baird, D.J., Soares, A.M.V.M. and Guilhermino, L. (2001) Biochemical factors contributing to response variation among resistant and sensitive clones of *Daphnia magna* Straus exposed to ethyl parathion. *Ecotoxicology and Environmental Safety* 49, 155-163.
- Barata, C., Baird, D.J., Medina, M., Albalat, A. and Soares, A.M.V.M. (2002) Determining the ecotoxicological mode of action of toxic chemicals in meiobenthic marine organisms: stage-specific short tests with *Tisbe battagliai*. *Marine Ecology Progress Series* 230, 183-194.
- Barata, C., Baird, D.J., Mitchell, S.E. and Soares, A.M.V.M. (2002) Among and within population variability in tolerance to toxic stress in natural populations of *Daphnia magna*. Implications for risk assessment. *Environmental Toxicology & Chemistry* 21, 1058-1064.
- Barata, C., Baird, D.J. and Soares, A.M.V.M. (2002) Demographic responses of a tropical cladoceran *Moinodaphnia macleayi* to cadmium: effects of food supply and density. *Ecological Applications* 12, 552-564.
- Barata, C., Markich, S.J., Baird, D.J., Taylor, G.J. and Soares, A.M.V.M. (2002) Genetic variability in sublethal tolerance to mixtures of cadmium and zinc in clones of *Daphnia magna* Straus. *Aquatic Toxicology* 60, 85-99.
- Barata, C., Medina, M., Telfer, T. and Baird, D.J. (2002) Determining demographic effects of cypermethrin in the marine copepod *Acartia tonsa*: stage-specific short tests versus life-table tests. *Archives of Environmental Contamination and Toxicology* 42, 17-22.
- Barata, C., Baird, D.J. and Soares, A.M.V.M. (2002) Determining genetic variability in population response to toxic stress among and within populations of *Daphnia magna* in the field. *Environmental Science & Technology* 36, 3045-3049.
- Barata, C., Markich, S.J., Baird, D.J. and Soares, A.M.V.M. (2002) The relative importance of water and food as cadmium sources to *Daphnia magna* Straus. *Aquatic Toxicology* 61, 143-154.
- Barman, B., Little, D. C. and Edwards, P. (2002) Small-scale fish culture in Northwest Bangladesh: a participatory appraisal focusing on the role of tilapia. In: *Rural Aquaculture*, pp. 227-244. CABI Publishing, Wallingford.
- Bartley, D. M., Rana, K. J. and Imminck, A. J. (2002) The use of inter-specific hybrids in aquaculture. In: *Reviews in Fish Biology and Fisheries* 10, 325-337.
- Basavaraju, Y., Mair, G.C., Mohan Kumar, H.M., Pradeep Kumar, S., Keshavappa, G.Y. and Penman, D.J. (2002). An evaluation of triploidy as a potential solution to the problem of precocious sexual maturation in common carp, *Cyprinus carpio*, in Karnataka, India. *Aquaculture* 204, 407-418.
- Bell, A.S. and Sommerville, C. (2002) Molecular evidence for the synonymy of two species of *Apatemon* Szidat, 1928, *A. gracilis* (Rudolphi, 1819) and *A. annuligerum* (von Nordmann, 1832) (Digenea: Strigeidae) parasitic as metacercariae in British fishes. *Journal of Helminthology* 76, 193-198.
- Bell, A.S., Sommerville, C. and Gibson, D.I. (2002) Multivariate analyses of morphometric features from *Apatemon gracilis* (Rudolphi, 1819) and *A. annuligerum* (v. Nordmann, 1832) (Digenea: Strigeidae) metacercariae. *Systematic Parasitology* 51, 121-133.
- Bell, J.G. (2001) Farmed fish and human health: consequences of fish oil replacement with vegetable oils in aquaculture feeds. *Trouw Outlook* 16, 10-11.
- Bell, J.G. (2002) Essential fatty acids and inflammatory cytokines. *The Autism File* 9, 9.
- Bell, J.G. (2002) Phospholipid spectrum disorders in autism. *The Autism File* 9, 16-17.
- Bell, J.G., Henderson, R.J., Tocher, D.R., McGhee, F., Dick, J.R., Porter, A., Smullen, R.P. and Sargent, J.R. (2002) Substituting fish oil with crude palm oil in the diet of Atlantic salmon (*Salmo salar*) affects muscle fatty acid compositions and hepatic fatty acid metabolism. *Journal of Nutrition* 132, 222-230.
- Bell, J.G., McEvoy, L.A., Estevez, A., Shields, R.J. and Sargent, J.R. (2001) Optimising highly unsaturated fatty acid levels in first feeding marine fish larvae. In: *Larvi 01- Fish and Shellfish Larviculture Symposium* (C.I. Hendry, G. Van Stappen, M. Wille and P. Sorgeloos eds), pp. 54-57. European Aquaculture Society, Special Publication No. 30. Oostende, Belgium.
- Bell, M.V., Dick, J.R. and Porter A.E.A. (2001) Biosynthesis and tissue deposition of docosahexaenoic acid (22:6n-3) in rainbow trout (*Oncorhynchus mykiss*). *Lipids* 36, 1153-1159.
- Beveridge, M.C.M. and Little, D.C. (2002) History of aquaculture in traditional societies. In: *Ecological Aquaculture* (B.A. Costa-Pierce, ed.), pp. 3-29. Blackwell Science, Oxford.
- Bromage, N., Mazzora, C., Davie, A., Alorend, E., Bruce, M., Bell, G. and Porter, M. (2001) Optimising broodstock performance: maturation, fecundity, and gamete quality. In: *Larvi 01- Fish and Shellfish Larviculture Symposium* (C.I. Hendry, G. Van Stappen, M. Wille and P. Sorgeloos eds), pp. 87. European Aquaculture Society, Special Publication No. 30. Oostende, Belgium.
- Brown, J.H., McCauley, S., Ross, B., Taylor, A.C. and Huntingford, F. (2002) A test of two methods for marking larvae and post larvae of the giant freshwater prawn, *Macrobrachium rosenbergii*. *Aquaculture Research* 33, 1-6.
- Bulcock, P., Bostock, J. C., Beveridge, M. C. M. and Telfer, T. C. (2001) The evolution of aquaculture feed supply systems. *Eurofish* 2, 74-76.
- Campos-Ramos, R., Harvey, S.C., Masabanda, J.S., Carrasco, L.A.P., Griffin, D.K., McAndrew, B.J., Bromage, N.R. and Penman, D.J. (2001) Identification of putative sex chromosomes in the blue tilapia, *Oreochromis aureus*, through synaptonemal complex and FISH analysis. *Genetica* 111, 143-153.
- Ciftci, Y., Castilho, R. and McAndrew, B.J. (2002) More polymorphic microsatellite markers in the European seabass (*Dicentrarchus labrax* L.). *Molecular Ecology Notes* 10, 1046.
- Combroux, I., Bornette, G., Willby, N.J. and Amoros, C. (2001) Regenerative strategies of aquatic plants in disturbed habitats: the role of the propagule bank. *Archiv für Hydrobiologie* 152, 215-235.
- Conrad, A.U., Comber, S.D. and Simkiss, K. (2002) Pyrene bioavailability; effect of sediment-chemical contact time on routes of uptake in an oligochaete worm. *Chemosphere* 49: 447-454.
- Corsin, F., Turnbull, J.F., Hao, N.V., Mohan, C.V., Phi, T.T., Phuoc, L.H., Tinh, N.T.N. and Morgan, K.L. (2002) Design and execution of an epidemiological study on white spot disease in black tiger shrimp (*Penaeus monodon*). *Preventative Veterinary Medicine* 53, 117-132.
- Corsin, F., Turnbull, J.F., Hao, N.V., Mohan, C.V., Phi, T.T., Phuoc, L.H., Tinh, N.T.N. and Morgan, K.L. (2001) Risk factors associated with white spot syndrome virus infection in a Vietnamese rice-shrimp farming system. *Diseases of Aquatic Organisms* 47, 1-12.
- Coward, K. and Bromage, N.R. (2002) Quantification of ovarian condition in fish: a safer, more precise alternative to established methodology. *Aquatic Living Resources* 15, 259-261.
- Coward, K. and Bromage, N.R. (2002) Stereological point-counting; an accurate method for assessing ovarian function in tilapia. *Aquaculture* 212, 383-401.
- Coward, K., Mattioli, M. and Bromage, N.R. (2000) Use of pregnant mares serum gonadotropin to prime the post-spawned ovary of *Tilapia zillii* (Gervais) prior to the induction of spawning with human chorionic gonadotropin. *Journal of Aquaculture in the Tropics* 15, 19 - 22.
- Davies, B. and Bromage, N. (2002) The effects of fluctuating seasonal and constant water temperatures on the photoperiodic advancement of reproduction in female rainbow trout, *Oncorhynchus mykiss*. *Aquaculture* 205, 183-200.
- Del Rio-Rodriguez, R.E. and Turnbull, J.F. (2002) Aerobic microflora of imported ornamental fish from Singapore and South America. Part 2: Antimicrobial resistant profiles of motile aeromonads. *Fish Veterinary Journal* 6, 1-21.
- Dixon, T. J., Taggart, J. B. and George, S. G. (2002) Application of real time PCR determination to assess interanimal variabilities in CYP1A induction in the European flounder (*Platichthys flesus*). *Marine Environmental Research* 54, 267-270.
- Duncan, N.J., Thrush, M.A., Elliott, A.K. and Bromage, N.R. (2002) Seawater growth and maturation of Atlantic salmon (*Salmo salar*) transferred to sea at different times during the year. *Aquaculture* 213, 293-309.
- Edwards, P., Little, D.C. and Demaine, H. (eds.) (2002) *Rural Aquaculture*. CABI Publishing, Wallingford. 358pp.
- Edwards, P., Little, D. C. and Demaine, H. (2002) Issues in rural aquaculture. In: *Rural Aquaculture*, pp. 323-340. CABI Publishing, Wallingford.
- Ellis, T., Scott, A. P., Bromage, N., North, B. and Porter, M. (2001) What is stocking density? *Trout News* 32, 35-37.
- Ellis, T., North, B., Scott, A. P., Bromage, N. R, Porter, M. and Gadd, D. (2002) The relationship between stocking density and welfare in farmed rainbow trout. *Journal of Fish Biology* 61, 493-531.
- Fariás, A., Bell, J.G., Uriate, I., Henderson, R.J. and Sargent, J.R. (2001) Effect of temperature and diet on growth and lipid composition of Chilean scallop *Argopecten purpuratus* (L.) larvae. In: *Larvi 01- Fish and Shellfish Larviculture Symposium* (C.I. Hendry, G. Van Stappen, M. Wille and P. Sorgeloos eds), pp. 198-201. European Aquaculture Society, Special Publication No. 30. Oostende, Belgium.
- Ferguson, H.W., Turnbull, J., Shinn, A., Thompson, K., Dung, T.T. and Crumlish, M. (2001) Bacillary necrosis in farmed *Pangasius* spp. from the Mekong Delta. *Journal of Fish Diseases* 24, 509-514.
- George, S.G. and Leaver, M. (2002) Allelic variations in the plaice UGT1B1 gene. *Marine and Environmental Research* 54, 259-262.

- George, S.G. and Taylor, B. (2002) Molecular evidence for multiple UDP-glucuronosyltransferase gene families in fish. *Marine and Environmental Research* 54, 253-257.
- Glover, K.A., Nilson, F., Skaala, O., Taggart, J.B. and Teale, A.J. (2002) Differences in susceptibility to sea lice infection between a sea run and a freshwater resident population of brown trout. *Journal of Fish Biology* 59, 1512-1519.
- Glover, K.A., Taggart, J.B., Skaala, Ø. and Teale, A. J. (2001) Comparative performance of juvenile sea trout families in high and low feeding environments. *Journal of Fish Biology* 59, 105-115.
- Halfyard, L.C., Parrish, C.C., Watkins, J. and Jauncey, K. (2001) Fatty acid and amino acid profiles of eggs from the common wolffish, *Anarhichas lupus*. *Bulletin of the Aquaculture Association of Canada* 2001, 60-63.
- Harvey, S.C., Campos-Ramos, R., Kennedy, D.D., Ezaz, M.T., Bromage, N.R., Griffin, D.K. and Penman, D.J. (2002) Karyotype evolution in tilapia: mitotic and meiotic chromosome analysis of *Oreochromis karongae* and *O. niloticus* x *O. karongae* hybrids. *Genetica* 115,169-177.
- Harvey, S.C., Masabanda, J., Carrasco, L.A.P., Bromage, N.R., Penman, D.J. and Griffin, D.K. (2002) Molecular-cytogenetic analysis reveals sequence differences between the sex chromosomes in *Oreochromis niloticus*: evidence for an early stage of sex chromosome evolution. *Cytogenetics and Genome Research* 97, 76-80.
- Harvey, S.C., Powell, S.F., Kennedy, D.D., McAndrew, B.J. and Penman, D.J. (2002) Karyotype analysis of *Oreochromis mortimeri* and *Sarotherodon melanotheron*. *Aquaculture Research* 33, 339-342.
- Hastings, N., Agaba, M., Tocher, D.R., Leaver, M.J., Dick, J.R., Sargent, J.R. and Teale, A.J. (2001) A vertebrate fatty acid desaturase with $\Delta 6$ and $\Delta 5$ activities. *Proceedings of the National Academy of Sciences USA*, 98, 14304-14309.
- Hilsdorf, A.W., Penman, D.J., Cunha Farias, E. and McAndrew, B.J. (2002) Melanophore appearance in wild and red tilapia embryos. *Pigment Cell Research* 15, 57-61.
- Iraqi, F., Sekikawa, K., Rowlands, J. and Teale, A. (2001) Susceptibility of TNF- α genetically deficient mice to *Trypanosoma congolense* infection. *Parasite Immunology* 23, 445-451.
- Iqbal, Z. and Wootten, R. (2001) Development of *Proteocephalus filicollis*, a cestode, in the copepod intermediate host under experimental conditions. *Science International (Lahore)* 13, 59-65.
- Iqbal, Z. and Wootten, R. (2002) Ultrastructure of the embryonic envelopes of *Proteocephalus filicollis* Rudolphi (Cestode: Proteocephalidae). *Pakistan Journal of Zoology* 34, 57-63.
- Jung, T.S., Thompson, K.D. and Adams, A. (2001) Determination of the attachment of *Photobacterium damsela* subsp. *piscicida* to fish cells using an enzyme immunosorbent assay. *Fish Pathology* 36, 201-206.
- Jung, T.S., Thompson, K.D. and Adams, A. (2001) A comparison of sialic acid between different isolates of *Photobacterium damsela* subsp. *piscicida*. *Fish Pathology* 36, 217-224.
- Kwon, J.Y., McAndrew, B.J. and Penman, D.J. (2002) Inhibition of aromatase activity suppresses high-temperature feminisation of genetic male (YY) Nile tilapia, *Oreochromis niloticus*. *Journal of Fish Biology* 60,625-636.
- Little, D.C., Tuan, P.A. and Barman, B.K. (2002) Health management issues in freshwater hatcheries, nurseries and fry distribution, with emphasis on experiences in Viet Nam and Bangladesh. In: *Primary Aquatic Animal Health Care in Rural Small-Scale Aquaculture Development*. FAO Fisheries Technical Paper 406, pp. 141-146. FAO, Rome.
- Little, D.C. and Innes Taylor, N. (2002) Fry nursing in rice-fish systems. In: *Integrated Agriculture-Aquaculture. A Primer*. FAO Fisheries Technical Paper 407, pp. 139-141. FAO, Rome.
- Little, D.C., Satapornvanit, A. and Edwards, P. (2002) Freshwater fish seed in Asia. In: *Rural Aquaculture*, pp. 185-196. CABI Publishing, Wallingford.
- Macintosh, D. J., Ashton, E.C. and Havanon, S. (2002) Mangrove rehabilitation and intertidal biodiversity: a study of the Ranong mangrove ecosystem, Thailand. *Estuarine, Coastal and Shelf Science* 55, 331-345.
- Macintosh, D. J., Overton, J. L. and Thu, H. V. T. (2002) Confirmation of two common mud crab species (genus: *Scylla*) in the mangrove ecosystem of the Mekong Delta. *Journal of Shellfish Research*, 259-265.
- Martínez Palacios, C.A., Barriga Tovar, E., Taylor, J.F., Ríos Durán, G., and Ross, L.G. (2001) Effect of temperature on growth and survival of *Chirostoma estor estor*, Jordan 1879, monitored using a simple video technique for remote measurement of length and mass of larval and juvenile fishes. *Aquaculture* 209, 369-377.
- Martínez-Lara, E., Leaver, M.J. and George, S.G. (2002) Evidence from heterologous expression of glutathione S-transferases A and A1 of the plaice (*Pleuronectes platessa*) that their endogenous role is in detoxification of lipid peroxidation products. *Marine Environmental Research* 54, 263-266.
- Martínez-Palacios, C.A., Chávez Sánchez, Ma.C., Papp, G.S., Abdo de la Parra, I. and Ross, L.G. (2002) Observations on spawning, early development and growth of the puffer fish *Sphoeroides annulatus* (Jenyns, 1843). *Journal of Aquaculture in the Tropics* 17, 59-66.
- McWilliam, R.A. and Baird, D.J. (2002) Post-exposure feeding depression: a new toxicity endpoint for use in laboratory and field bioassays with *Daphnia magna*. *Environmental Toxicology & Chemistry* 20,1198-1205.
- McWilliam, R.A. and Baird, D.J. (2002) Application of post-exposure feeding depression bioassays with *Daphnia magna* for assessment of toxic effluents in rivers. *Environmental Toxicology & Chemistry* 22, 1462-1468.
- Medina, M., Barata, C., Telfer, T.C. and Baird, D.J. (2002) Age- and sex-related variation in sensitivity to contaminants in the marine copepod *Acartia tonsa*. *Archive of Environmental Contamination and Toxicology* 42, 17-22.
- Mercure, F., Holloway, A. C., Tocher, D. R., Sheridan, M. A., Van Der Kraak, G. and Leatherland, J. F. (2001) Influence of plasma lipid changes in response to 17 β -oestradiol stimulation on plasma growth hormone, somatostatin, and thyroid hormone levels in immature rainbow trout. *Journal of Fish Biology* 59, 605-615.
- Mohan, C.V., Corsin, F., Thakur, P.C., Padiyar, P.A., Madhusudan, M., Turnbull, J.F., Hao, N.V. and Morgan, K.L. (2002) Usefulness of dead shrimp specimens to study the epidemiology of white spot syndrome virus (WSSV) and chronic bacterial infection. *Diseases of Aquatic Organisms* 50, 1-8.
- Morris, D. C., Morris, D. J. and Adams, A. (2002) Development of improved PCR to prevent false positives and false negatives in the detection of *Tetracapsula bryosalmonae*, the causative agent of proliferative kidney disease. *Journal of Fish Diseases* 25, 483-490.
- Morris, D. C., Morris, D. J. and Adams, A. (2002) Molecular evidence for the release of *Tetracapsula bryosalmonae* from brown trout, *Salmo trutta* L., into the environment. *Journal of Fish Diseases* 25, 501-504.
- Morris, D. J., Morris, D. C. and Adams, A. (2002) Development and release of a malacosporan (Myxozoa) from *Plumatella repens* (Bryozoa: Phylactolaemata). *Folia Parasitologica* 49, 25-34.
- Morris, D. J. and Adams, A. (2002) PCR and *in situ* hybridisation of *Tetracapsula bryosalmonae* (PKX) the agent of proliferative kidney disease. *Molecular Diagnosis of Salmonid Diseases* (C. Cunningham, ed), pp. 299-313. Kluwer Publishing.
- Morris, D.J. and Adams, A. (2002) Development of *Schroedera plumatellae* gen. n. et sp. n. (Microsporidia) in *Plumatella fungosa* (Bryozoa, Phylactolaemata). *Acta Protozoologica* 4, 383-396.
- Morris, D. J., Turgut, E. and Thompson, K. D. (2002) The use of melanin bleaching for immunohistochemistry detection of *Renibacterium salmoninarum*. *Bulletin of the European Association of Fish Pathologists* 22, 33-36.
- Mourente, G., Díaz-Salvago, E., Bell, J.G. and Tocher, D.R. (2002) Increased activities of hepatic antioxidant defence enzymes in juvenile gilthead sea bream (*Sparus aurata* L., Osteichthyes, Sparidae) fed dietary oxidised oil: attenuation by dietary vitamin E. *Aquaculture* 214, 343-361.
- Murray, F., Little, D.C., Haylor, G., Felsing, M., Gowing, J. and Koodithuwakku, S.S. (2002) A framework for research into the potential for integration of fish production in irrigation systems. In: *Rural Aquaculture*, pp. 29-40. CABI Publishing, Wallingford.
- Naessens, J., Teale, A.J. and Sileghem, M. (2002) Identification of mechanisms of natural resistance to African trypanosomiasis in cattle. *Veterinary Immunology and Immunopathology* 87, 187-194.
- Nagl, S., Tichy, H., Mayer, W. E., Samonte, I.E., McAndrew, B.J. and Klein, J. (2001) Classification and phylogenetic relationships of African tilapiine fishes inferred from mitochondrial DNA sequences. *Molecular Phylogenetics and Evolution* 20, 361-374.
- Overton, J. L. and Macintosh, D. J. (2002) Estimated size at sexual maturity for female mud crabs (genus *Scylla*) from two sympatric species within Ban Don Bay, Thailand. *Journal of Crustacean Biology* 22, 790-797.
- Özer, A., Wootten, R. and Shinn, A.P. (2002) Survey of actinosporan types (Myxozoa) belonging to seven collective groups found in a freshwater salmon farm in Northern Scotland. *Folia Parasitologica* 49, 189-210.
- Özer, A., Wootten, R. and Shinn, A.P. (2002) Infection prevalence (%), seasonality and host specificity of actinosporan types in an Atlantic salmon fish farm located in Northern Scotland. *Folia Parasitologica* 49, 263-268.
- Peck, M.R., Klessa, D.A. and Baird, D.J. (2002) A tropical sediment toxicity test using the dipteran *Chironomus crassirostris* to test metal bioavailability with sediment pH change in tropical acid-sulfate sediments. *Environmental Toxicology and Chemistry*, 21, 720-728.
- Penman, D.J., Griffin, D.K., Masabanda, J., Harvey, S.C., Campos Ramos, R., Carrasco, L.A.P. and Bromage, N.R. (2002) Microdissection of *Oreochromis niloticus* putative sex chromosomes and DOP-PCR produces chromosome-specific FISH probes. *Aquaculture* 204, 237-28.
- Penman, D.J., Harvey, S.C., Masabanda, J., Carrasco, L.A.P., Bromage, N.R., and Griffin, D. (2001) Molecular-cytogenetic analysis of differentiation of sex chromosomes in *Oreochromis niloticus*: evidence that these represent early stages of sex chromosome evolution? *Chromosome Research* 9 (S1), 114-115.
- Penman, D.J., Hussain, M.G., McAndrew, B.J. and Mazid, M.A. (eds) (2002) *Genetic Management and Improvement of Exotic Carp Species in Bangladesh: Proceedings of a DFID-AFGRP/BFRI Workshop*, 12-14 Feb 2002, Dhaka, Bangladesh. BFRI, Mymensingh, Bangladesh. 123p.
- Penman, D.J., Mair, G.C., McAndrew, B.J., Hussain, M.G., Basavaraju, Y. and Tuan, P.A. (2002) Genetic management of non-indigenous carps for low input aquaculture in Asia. *Aquaculture News* 28,19-22.
- Pérez, O.M., Telfer, T.C., Ross, L.G. and Beveridge, M.C.M. (2002) Geographical information systems (GIS) as a tool for modelling waste distribution under marine fish cages. *Estuarine, Coastal and Shelf Science* 54, 761-768.
- Pond, D.W., Allen, C.E., Bell, M.V., Van Dover, C.L., Fallick, A.E., Dixon, D.R. and Sargent, J.R. (2002) Origins of long-chain polyunsaturated fatty acids in the hydrothermal vent worms, *Ridgea piscesae* and *Protis hydrothermica*. *Marine Ecology Progress Series* 225, 219-226.
- Putinaowarat, S., Thompson, K.D., Kolk, A. and Adams, A. (2002) Identification of *Mycobacterium* spp. isolated from snakehead (*Channa striata*) and Siamese fighting fish (*Betta splendens*) using polymerase chain reaction reverse cross blot (PCR-RCBH). *Journal of Fish Diseases* 24, 1-9.

- Rahman, M. A., Ronyai, A., Engidaw, B. Z., Jauncey, K., Hwang, G., Smith, A., Roderick, E., Penman, D., Varadi, L. and Maclean, N. (2001) Growth and nutritional trials on transgenic Nile tilapia containing an exogenous fish growth hormone gene. *Journal of Fish Biology* 59, 62-78.
- Rana, K. J. (2001) Tilapia production in Africa. In: *Tilapia: Production, Marketing and Technological Developments: Proceedings of the Tilapia 2001 International Technical and Trade Conference on Tilapia*(Subasinghe S. and Singh T., eds) 28th -30 May 2001, Kuala Lumpur, Malaysia. pp. 28-32.
- Sargent, J. R., Tocher, D.R. and Bell, J.G. (2002) The lipids. In: *Fish Nutrition*, 3rd edition (Halver, J. E. and Hardy, R.W, eds), pp. 181-257. Academic Press, San Diego.
- Sargent, J.R., Bell, J.G., McGhee, F., McEvoy, J. and Webster, J.L. (2001) The nutritional value of fish. In: *Farmed Fish Quality* (S. C. Kestin and P.D. Warriss eds), Fishing News Books, Oxford.
- Shinn, A.P., Kay, J.W. and Sommerville, C.(2002) Towards an automated system for the identification of notifiable pathogens. *Trout News* 33, 26-28.
- Smith, V.J., Chisholm, J.R.S and Brown, J.H. (2001). Development ecology of immunity in crustaceans. In: *Environment and Animal Development: Genes, Life Histories and Plasticity*, (D. Atkinson and M. Thorndyke eds), pp. 153-172. BIOS Scientific Publishing, Oxford.
- Steiropoulos, N.A., Yuksel, S.A., Thompson, K.D., Adams, A. and Ferguson, H.W. (2002) Detection of *Rickettsia*-like organisms (RLOs) in European sea bass (*Dicentrarchus labrax*, L.) by immunohistochemistry, using rabbit anti-*Piscirickettsia salmonis* serum. *Bulletin of the European Association of Fish Pathologists* 22, 428-432.
- Stone, J., Roy, W.J., Sutherland, I.H., Ferguson, H.W., Sommerville, C., Richards, R.H. and Endris, R.G. (2002) Safety and efficacy of emamectin benzoate administered in feed to Atlantic salmon *Salmo salar* (L.) smolts in freshwater as a preventative treatment against infestations of sea lice, *Lepeophtheirus salmonis* (Kroyer). *Aquaculture* 210, 21-34.
- Stone, J., Boyd, S., Sommerville, C. and Rae, G.H. (2002) An evaluation of freshwater bath treatments for the control of sea lice, *Lepeophtheirus salmonis* (Kroyer), infections in Atlantic salmon, *Salmo salar* L. *Journal of Fish Diseases* 25, 371-373.
- Taylor, A.C., Ross, B., McCauley, S., Brown, J.H. and Huntingford, F. (2002) Inter- and intra-individual variation in resting oxygen consumption in post-larvae of the giant freshwater prawn, *Macrobrachium rosenbergii* (De Man). *Comparative Biochemistry and Physiology (A)* 132, 459-466.
- Taylor, G. A., Baird, D. J. and Soares, A.M.V.M. (2002) Ecotoxicology of contaminants in tropical wetlands: the need for greater ecological relevance in risk assessment. *SETAC Globe* 3, 27-28.
- Telfer, T.C. and Beveridge, M.C.M. (2002) Aquaculture: salmon farming. In: *Encyclopaedia of Global Environmental Change - Volume 3, Causes and Consequences of Global Environmental Change* (Douglas, I. ed), pp. 200-204. Wiley and Sons, Chichester.
- Telfer, T.C. and Beveridge, M.C.M. (2001) Monitoring environmental effects of marine fish aquaculture. *Cahiers Options Mediterranennes* 55, 75-84.
- Telfer, T.C. and Beveridge, M.C.M. (2001) Practical experiences: the northern European perspective. *Cahiers Options Mediterranennes* 55, 85-90.
- Thakur, P.C., Corsin, F., Turnbull, J.F., Shankar, K.M., Hao, N.V., Padiyar, P.A., Madhusudhan, M., Morgan, K.L. and Mohan, C.V. (2002) Estimation of prevalence of white spot syndrome virus (WSSV) by polymerase chain reaction in *Penaeus monodon* postlarvae at time of stocking in shrimp farms of Karnataka, India: a population-based study. *Diseases of Aquatic Organisms* 49, 235-243.
- Thompson, K.D., Penman, D.J., McAndrew, B.J. and Sarder, M.R.I. (2002) Scotland study evaluates immune responses, disease resistance in clonal lines of tilapia. *Global Aquaculture Advocate* 5, 34-35.
- Tocher, D. R., Bell, J. G., MacGlaughlin, P., McGhee, F. and Dick, J. R. (2001) Hepatocyte fatty acid desaturation and polyunsaturated fatty acid composition of liver in salmonids: effects of dietary vegetable oil. *Comparative Biochemistry and Physiology* 130, 257-270.
- Tocher, D. R., Mourente, G., Van der Eeken, A., Evjemo, J.O., Diaz, E., Bell, J. G., Geurden, I., Lavens, P. and Olsen, Y. (2002) Effects of dietary vitamin E on antioxidant defence mechanisms of juvenile turbot (*Scophthalmus maximus* L.), halibut (*Hippoglossus hippoglossus* L.) and sea bream (*Sparus aurata* L.). *Aquaculture Nutrition* 8, 195-207.
- Tocher, D.R., Agaba, M., Hastings, N., Bell, J.G., Dick, J.R. and Teale, A.J. (2001) Nutritional regulation of hepatocyte fatty acid desaturation and polyunsaturated fatty acid composition in zebrafish (*Danio rerio*) and tilapia (*Oreochromis nilotica*). *Fish Physiology and Biochemistry* 24, 309-320.
- Tocher, D.R., Bell, J.G., Diaz, E., Evjemo, J.O., Mourente, G., Olsen, Y., Van der Eecken, A. and Wille, M. (2001) Comparative study of the antioxidant defence system and growth performance of fish fed variable levels of oxidised oil and vitamin E. In: *Larvi 01- Fish and Shellfish Larviculture Symposium* (C.I. Hendry, G. Van Stappen, M. Wille and P. Sorgeloos eds), pp. 602-605. European Aquaculture Society, Special Publication No. 30. Oostende, Belgium.
- Tucker, C. S., Sommerville, C. and Wootten, R. (2002) Does size really matter? Effects of fish surface area on the settlement and initial survival of *Lepeophtheirus salmonis*, an ectoparasite of Atlantic salmon *Salmo salar*. *Diseases of Aquatic Organisms* 49, 145-152.
- Tucker, C.S., Norman, R., Shinn, A.P., Bron, J.E., Sommerville, C. and Wootten, R. (2002) A single cohort, time delay model of the life cycle of the salmon louse (*Lepeophtheirus salmonis*) on Atlantic salmon *Salmo salar*. *Fish Pathology* 37, 107- 118.
- Vatsos, I. N., Thompson, K. D. and Adams, A. (2002) Identification and enumeration of *Flavobacterium psychrophilum* by *in situ* hybridisation and immunofluorescent antibody technique (IFAT). *Aquaculture Research* 33, 1087-1090.
- Wambugu, J., Kanguha, E., Hanotte, O., Davis, S., Taylor, J. Skow, L., Brunner, R., Schwerin, M., Teale, A. and Iraqi, F. (2001) Identification of two polymorphic microsatellite repeats on a bovine *TNFA*-containing BAC clone. *Animal Genetics* 32, 105-106.
- Willby, N.J., Pygott, J.R. and Eaton, J.W. (2001) Inter-relationships between standing crop, biodiversity and trait attributes of aquatic vegetation in artificial waterways. *Freshwater Biology* 43, 43-74.
- Willby, N.J., Pulford, I.D and Flowers, H.D. (2001) Nutrient concentrations in herbaceous wetland vegetation with respect to plant growth strategies and nutrient limitation. *New Phytologist* 152, 463-468.



Cover picture:

Ethnic minorities in mountainous areas of SE Asia, such as this Tai woman in northern Vietnam, manage traditional aquaculture systems. In this region tilapias have become an important species that are managed as self-recruiting stocks in and around rice fields and mainly used for home consumption.