An expert approach to global change

Leading NorMER scientists **Nils Chr. Stenseth** (Chair), **Carl Folke** (co-Chair), and **Philippe Cury** (Centre Advisory Panel Chair) discuss a new coordinated strategy for managing the impact of global changes on Nordic marine life, using Atlantic cod as an example of the challenges ahead



What is the primary focus of The Nordic Centre for Research on Marine Ecosystems and Resources under Climate Change (NorMER)?

CF: In this research-based programme, we are using the Atlantic cod as an example of ecological, economic and social interactions and interdependencies. The cod represent challenges spanning climate change, eutrophication and overfishing, and insights gained will be useful for other fisheries. For example, in the Baltic Sea, focusing on managing the cod alone will only be successful as an incidental effect. A broader approach takes into account the dynamics of cod and its prey species – the sprat – as well as eutrophication and the role of ocean currents in cod recruitment.

Marine ecosystems are under pressure from both anthropogenic climate change and high exploitation rates. What are the key challenges that fisheries managers and scientists face as a result of this?

NCS: Managers and scientists each face different sets of interlinked and non-exclusive challenges.

For managers, a few of these include: identifying and fixing weaknesses of current governance of resources; improving knowledge of the biological, environmental and economic drivers affecting fish stocks; and integration of scientific and management approaches. Scientists must: improve links between statistical and mechanistic approaches to improve predictions of climate change effects; broaden the scope of studies through increased interdisciplinary efforts; and develop more effective training programmes for young researchers that are relevant beyond the academic sphere. The overall challenge is to realise that these tasks are truly interlinked, and in order to move forward, they must be overcome together.

How does NorMER's programme differ from the traditional isolated in-depth studies and provide a vision for the future of science?

CF: It is truly interdisciplinary in terms of the overall shared vision and focus. We draw on specialist knowledge and the interests of the researchers predominantly in biology and economics, but also other political sciences engaged with governance to provide depth, always in the context of the broader picture and challenge. It represents basic interdisciplinary science for improved understanding and with results and insights generated that will help inspire and guide management of marine ecosystems.

In what ways does the interdisciplinary and collaborative approach of the project lead to a stronger Nordic position on leading scientific endeavours in both Europe and globally?

PC: It is obvious that science is not an isolated process, but requires groups to work together on challenging topics. This is how leading scientific groups works today; there is no other real way to conduct high quality science in our fields with the aim to answer broad and difficult questions regarding the future of marine resources.

What impact do you expect the research project to have on industry and policy managers and how do you aim to ensure that marine ecosystem management policies are updated to sustain healthy fisheries?

CF: As in the other Nordic areas, in the Baltic Sea region there are strong links between the NorMER programme and governments at national levels, but also regionally and locally through interactions with fishermen, municipalities and other actors. At the Stockholm Resilience Centre we host the Baltic Nest Institute that feeds understanding into the Helsinki Commission on Baltic Sea Environment Protection (HELCOM), the body coordinating all nations on marine issues of the Baltic Sea and its catchment. NorMER has in general strong links to both policy and decision making.

How will the research conducted as part of NorMER be extended to other marine ecosystems?

PC: In both its structure and organisation NorMER will serve as an example for many other countries to organise their research around a key topic regarding a renewable or valuable resource. This initiative can also serve as a demonstration for organising an ecosystem approach to fisheries in many other world ecosystems.

Do you have any broader observations on changing attitudes in this field of research?

CF: As a general observation, there is currently an overall shift in perspective from conserving the environment or focussing on single resources towards recognition that economic and social development ultimately depends on the capacity of the biosphere and its ecosystems to be sustained. This calls for improved stewardship of ecosystems and the services they generate for human wellbeing. NorMER will contribute to this shift.

Adding depth to marine research

The **Nordic Centre for Research on Marine Ecosystems and Resources under Climate Change** offers a comprehensive, collaborative approach to studying the impact of human-driven changes on marine ecosystems across the Nordic region and beyond

HUMAN MADE environmental issues – including the impact of unsustainable fishing practices and numerous climate change drivers are at the top of the agenda for marine research and management in the Nordic region. Such challenges, by their very nature, must be dealt with collectively, but whilst a great deal of research activity already focuses on these topics, they are yet to be better coordinated as a whole. A new organisation has been formed to ensure that Nordic scientists can work collectively on a grand scale and join together to bring their findings to policy makers.

The Nordic Centre for Research on Marine Ecosystems and Resources under Climate Change (NorMER) is a new pan-Nordic collaborative project. The Centre aims to foster collaboration in the area of marine research between all Nordic research groups and several US institutions. The goal is to achieve a multidisciplinary strategy for research on the biological, ecological and management consequences of global climate change in marine ecosystems with a focus on the Nordic region.

COD FOR STARTERS

The first target on NorMER's agenda is the Atlantic cod (*Gadus morhua*). In the 1990s many cod stocks collapsed and have still failed to recover, even with the cessation of fishing. The Atlantic cod remains on the IUCN Red List of Threatened Species. NorMER will coordinate research on the Atlantic cod before expanding into other fisheries. Through the process of collaboration, NorMER plans to utilise their assessment of climate change on Nordic marine ecosystems to build new tools for predicting the biological impact of climate change. This will result in a quantifiable forecasting of the impacts of climate change on employment, profits and harvesting. This foresight is essential to guide policy makers to ensure that marine ecosystems remain balanced and that our seas flourish into the future.

ALL IN THE SAME BOAT

The key aim of the project is not just to convene Nordic marine experts, industry representatives and policy representatives annually, but to facilitate lasting interdisciplinary collaboration. This will be achieved by providing an ongoing framework for doctoral and postdoctoral students to work between partner institutions in placements that each last several months. It is hoped that the one species focus on the Atlantic cod will provide a focal point for scientists coming from all areas to combine their diverse expertise. This will establish a framework from which other areas of marine life can be studied on a comprehensive, structured, international basis. The organisation is driven by the key motives of addressing issues arising from climate change whilst maintaining a strong curiosity-driven scientific foundation. A united front will allow scientists to speak more loudly regarding the subjects that matter. Carl Folke, co-chair of NorMER, hints at further topics of interest: "Ocean acidification may be one of the largest challenges, strongly related to climate change. In a world with ecosystems and their dynamics shaped by humans, fisheries management and governance should expand the perspectives from single species management to stewardship of marine ecosystems of which the fisheries is part".

LEADING CHANGE

The project provides a respected platform from which a cross-section of scientists can communicate to the public, politicians and industry. The much anticipated launch of NorMER last October included presentations from the Norwegian Minister of Research and the Minister for Higher Education, Tora Aaslund, as well as the Norwegian Secretary of State, Kristine Gramstad, and the rector of the University of Oslo, Ole Petter Ottersen, alongside internationally recognised scientists.

Nils Chr. Stenseth, the chair of NorMER, has made it a key role of his institute to identify and bridge the gaps in knowledge between scientific disciplines and then translate these efforts into outputs that are used to inform policy managers or the public. Stenseth is now focussed on contributing to an improved

The key aim of the project is not just to convene Nordic marine experts, industry representatives and policy representatives annually but to facilitate lasting interdisciplinary collaboration

management of marine resources through solid basic science, and hopes to see NorMER become a tool to drive further problem-solving research through the combination of a series of curiosity-driven individual PhD and postdoctoral research projects, integrating ecology, evolution and economics. According to Stenseth, NorMER aims to lead the Nordic region forward based on 'EEEE' principles. The centre aims to provide a framework for integrating Ecological Sciences, Evolutionary Sciences, Economic Sciences and Excellence in Interdisciplinary Sciences. The focus on these principles shall enable NorMER to guide a new generation of marine experts with the skills, knowledge and resources to achieve real influence: "We want to evaluate the effects of climate variability on Nordic marine ecosystems with a strong scientific programme, while training a new generation of young researchers with the skills to link between science, industry and policy managers," Stenseth highlights.

BIG FISH

The NorMER board is composed of research leaders, all of whom have a high profile in the marine world as indicated by their distinguished extensive record of publications in high impact journals. NorMER has already appointed eight doctoral researchers and four postdoctoral researchers and will soon add nine additional doctoral students and four further postdoctoral student. All doctoral students will be overseen by the board to ensure they receive appropriate training; the relevant principal investigator handles the details of each project, but decisions regarding problems or overall research direction are to be made by a vote from the board.

MAELSTROM COD

Since its inception last year, NorMER has achieved an impressive level of funding for its first five years. The total budget now stands at NOK 74 million, with NOK 35 million contributed by NordForsk and approximately NOK 39 million contributed by the participating groups, which include research teams at the University of Oslo, the Stockholm Resilience Centre in Sweden, Åbo Adakemi University in Finland, the University of Helsinki in Finland, the Swedish Meteorological and Hydrological Institute in Sweden, Marine Academic Research in Iceland, the University of Faroe Islands, the Greenland Institute of Natural Resources, the University of Bergen in Norway, and the Technical University of Denmark.

ON THE SAME WAVELENGTH

The coalition of researchers that evolve through NorMER will emerge as a whole that is greater than the sum of its parts. This will provide NorMER with the ability to achieve lasting influence and to put theory into practice. NorMER could indeed contribute to building scenarios for the coming Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES). The challenges that this presents are summed up well by Philippe Cury, Chair of the Scientific Centre Advisory Panel: "This will require scientists to bring together all of their expertise in order to predict what the marine ecosystems will be in 20 to 50 years in a global climate change context. This requires structured, integrated scientific groups such as NorMER". The urgent focus on Atlantic cod underlines the importance of acting swiftly, collectively and decisively. The stewardship of the seas is the responsibility of all of us and if we do not act now to establish change in the correct direction we may soon see the extinction of portions of marine life that reside in the bedrock of our ecosystem. Due to the co-dependent nature of ecosystems, this project tackles an issue that affects us all and the lives of all our children. For this reason, it is a matter of the utmost significance.

NorMER

NORDIC CENTRE FOR RESEARCH ON MARINE ECOSYSTEMS AND RESOURCES UNDER CLIMATE CHANGE

OBJECTIVES

A Nordic Centre of Excellence that brings together the expertise of leading research groups from all Nordic countries, and several North American institutions, to implement a collective and multidisciplinary research strategy to explore the biological, economic and management consequences of global climate change on fisheries resources throughout the Nordic Region.

KEY COLLABORATORS

Nils Chr. Stenseth, University of Oslo • **Carl Folke**, Stockholm University • **Thomas Kiørboe**, Technical University of Denmark • **Erik Bonsdorff**, Åbo Akademy University • **Øyvind Fiksen**, University of Bergen • **Eyðfinn Magnussen**, University of the Faroe Islands • **Guðrún Marteinsdóttir**, University of Iceland • **Marko Lindroos**, University of Helsinki • **Markus Meier**, Swedish Meteorological and Hydrological Institute • **Helle Siegstad**, Greenland Institute of Natural Resources

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NILS CHR. STENSETH is Professor and Founding Chair of the Centre for Ecological and Evolutionary Synthesis (CEES; www.cees.uio.no) in the Department of Biology, University of Oslo and Chief Scientist II at the Institute of Marine Research in Bergen. He is Chair of the project.

CARL FOLKE is Professor and Science Director of the Stockholm Resilience Centre at Stockholm University and Director of the Beijer Institute of Ecological Economics. He is co-Chair of the project.

PHILIPPE CURY is a senior scientist at IRD, Director of the CRH based in Sète, France (www.umr-eme.org) and the scientific coordinator of the Eur-Oceans Consortium (www.eur-oceans.eu). He is Chair of the Centre Advisory Panel.

Lake expectations

The evolutionary responses of lake ecosystems to climate change are complex and include a myriad of variables. **Professors Asbjørn Vøllestad** and **Ian Winfield** outline work to predict this complexity

Can you explain the core objectives of the 'modelling ecosystems' project?

Our primary objective was to quantify and model the direct and indirect impacts of climate on a temperate lake ecosystem. Furthermore, as evolutionary biologists, we wanted to embed an evolutionary component into the community model. Our main interest is in the basic scientific merit of the project, and our hope was that our approach could reveal the importance of evolutionary processes in determining community responses under climate change.

Have you made any significant findings to date?

We have focused on understanding dynamics of the two main fishes in Lake Windermere (pike and perch), and how they interact. The system seems simple, but as we have shown in numerous analyses, the interactions between these two species and the effects of these interactions are actually highly complex.

On a more general level, we have been able to show how factors such as harvesting, changes in temperature, and introduction of a selective pathogen can have strong population dynamic effects that also lead to evolutionary change.

How do you combine simulated model predictions with scientific monitoring of Windermere in order to produce your results?

We use basic ecological principles and well-known ecological models, parameterised based on data from our own study system, to model relevant scenarios and ecosystem configurations. Using these 'realistic' models, we can ask questions to the models. For example, what would happen if temperature changed or if a new competitor invaded into the system? We try to phrase our questions in such a way that we can use our long-term observational data from Windermere to challenge the model outcome. In this way we come closer to understanding what might have happened in our system, as well as supporting or challenging existing theories.

How does the project tackle the challenge of translating findings from the individual to the population level in order to assess global warming impacts on population structure and dynamics?

Individual-based models easily become very complex, but such models allow for the investigation of very intricate relationship. On the other hand, the parameters used in these models have high uncertainty, and they interact in unknown ways. The main challenge is to construct realistic models, without introducing too much uncertainty. Thus, it becomes difficult to transfer results from these models to the population level.

What conclusions have you drawn from assessing the impact of global warming on size-structured fish populations?

We used a physiological size-structured consumer-resource model to understand temperature-dependent effects on consumer and resource vital rates. Our model predicts that increased temperature decreases the resource density despite higher resource growth rates, reflecting stronger intraspecific competition among consumers. At a critical temperature, the consumer population dynamics destabilise and shift from a stable equilibrium to competition-driven generation cycles. As a result, maximum age decreases and the proportion of younger and smaller-sized fish increases. Consequently, global warming may increase competition, favour smaller size classes, and induce regime shifts that destabilise population and community dynamics.

What are the implications of the research you have already conducted?

In short, we need to consider evolutionary effects of our actions as evolution happens here and now. These evolutionary developments, induced by changes in the global and local environment, have population dynamic consequences that should be taken into account when designing management plans. This idea is becoming increasingly accepted in the scientific community today, but more slowly in the various resource management agencies. Furthermore, our modelling exercises and also the analysis of the long-term datasets from Windermere show that impact on one part of the food web cascades through the food web. Understanding these interactions is not easy, but our results underscore the value of trying to understand and manage at an ecosystem level.

Can you outline the next stages in realising the goals of the project?

The project is now in its final stages but we are still analysing some theoretical models, as a follow-up of our ecosystem-based analyses. We are also finalising what we hope will be a new, very useful analytical approach to understanding our empirical data. We are building a structured population model (an integral projection model) where temporal variation in a state (here temperature) is allowed to vary continuously. It is a rather complex matter, using generalised linear mixed models, but will hopefully allow us to predict vital rates for our pike population under various predicted climate change scenarios.

Model behaviour

Reliable climate change models are integral to sound environmental policy-making. The **Modelling ecosystems under climate change** project underscores links between climate and evolutionary change within ecosystems

LAKES ARE OF major ecological, economic, recreational and cultural values. However, the ecosystems they support are under increasing pressure from climate change. The impacts of anthropogenic factors on freshwater lakes are well-documented, but the complex indirect effects on the evolution of such ecosystems are less well-known.

In response to this need for greater knowledge on evolutionary development in such ecosystems, Professor Asbjørn Vøllestad from the University of Oslo is coordinating the 'Modelling ecosystems under climate change: Windermere as a model lake system' project. This collaborative study addresses the effects of climate change on Windermere's most prevalent fish – perch and pike – from an evolutionary perspective.

The overall effect of changes in climate on evolution remains something of a mystery: "Global warming impacts on virtually all biota and ecosystems," Vøllestad outlines. "Many of these impacts are mediated through direct effects of temperature on individual vital rates. Yet, how this translates from the individual to the population level is still poorly understood."

The project – funded by the Research Council of Norway – is the result of a long-term collaboration between the Centre for Ecological and Evolutionary Synthesis (CEES) based in the Department of Biology at the University of Oslo and two UK institutions: the Freshwater Biological Association and the Centre for Ecology and Hydrology (CEH) in Lancaster. The CEES has worked with the CEH in particular for more than 10 years and also has an extended partnership with Ecole Normale Supérieure in Paris.

EMPIRICAL EVIDENCE AND MODELLING

The primary objective of the research is to quantify and model the direct and indirect impacts of climate on the Windermere ecosystem. This includes factors such as disease and temperature change. Focusing on Windermere's perch and pike populations, the team has taken a dual approach. Firstly, they analysed data gathered from over 60 years of scientific monitoring of Windermere, paying particular attention to a pathogen outbreak in 1976 which killed 98 per cent of the adult perch population. Secondly, the scientists underpinned their empirical findings with modelling work. They parameterised a stage-structured population model to simulate the effects of increased adult mortality caused by the pathogen outbreak of 1976. The model predicts biomass overcompensation by juvenile perch in response to increased adult mortality due to a shift in food-dependent growth and reproduction rates.

HARVEST SELECTION VERSUS NATURAL SELECTION

Data from the Windermere pike (the predator) and perch (the prey) shows a consideration of the relative strengths and directions of multiple selective pressures is needed to fully understand ecological dynamics.

The researchers found that harvest selection – in this case reducing the number of large pike in Windermere using gillnets – generates directional selection towards a smaller body size. In contrast, natural selection (chiefly cannibalism), selects larger pike. Trait changes track the adaptive peak, which are imposed by the dominant selective force. Individual lifetime body growth decreases at the start of the time series because harvest selection is strong and natural selection is too weak to override it.

However, natural selection favouring fast body growth strengthens across the time series in parallel with the increase in pike abundance and, presumably, cannibalism. Harvest selection is overridden by natural selection when the fishing effort dwindles, triggering a rapid increase in pike somatic growth.

Perch in Windermere are also subject to size-selective mortality. Pike select against small perch and a perch-specific pathogen selects against large perch. The strongest selective force drives perch trait change and ultimately determines the structure of trophic interactions. Before 1976, the strength of pike-induced selection overrode the strength of pathogen-induced selection. This drove a change towards larger, faster growing perch. Predation-driven increase in the proportion of large, infection-vulnerable perch presumably favoured the pathogen as a peak in predation in 1976 coincided with pathogen expansion and a massive perch kill. After 1976, the strength of pathogen-induced selection overrode the strength of predator-induced selection and drove a rapid change to smaller, slower growing perch. These changes made perch easier prey for pike and weaker competitors against juvenile pike. This ultimately increased juvenile pike survival and total pike numbers.

TURNING UP THE HEAT

The effect of temperature increase was examined using a physiological size-structured consumer-resource model. The model predicted that despite higher resource growth rates, raised temperature reduces resource density due to greater competition between predators. At the critical temperature dynamics become unstable which leads to competition-driven consumer cycles. Maximum age decreases, resulting in a greater proportion of smaller-sized and younger fish. The implications of this model are that global warming could increase competition, favour smaller size classes, and induce regime shifts that destabilise population and community dynamics.

PROFESSOR IAN WINFIELD OF CEH ON WINDERMERE WITH BBC REPORTERS

DRAWING CONCLUSIONS

The project concluded that although predators and pathogens exploited the same prey in Windermere, they did not operate competitively. Instead they worked in synergy, driving rapid prey trait change in opposite directions. However, these ecological and evolutionary processes operate on similar time scales, and the Darwinian theory is therefore highly relevant to the management and conservation of natural systems.

At a more general level, results demonstrate how factors such as harvesting, changes in temperature and the introduction of pathogens can affect population dynamics, which also leads to evolutionary change. Vøllestad explains that the findings are in keeping with existing suppositions on ecosystem evolution: "Life history theory indicates that evolutionary change

> Evolutionary change is almost inevitable given long-term changes in immune function

is almost inevitable given long-term changes in immune function and mortality rates and given relevant genetic variation. Our data gave us the opportunity to investigate the ecological and evolutionary effects of a perch-specific pathogen. To us, this was a very exciting opportunity, and the evolutionary effects seem very strong".

NOT WITHOUT CONTROVERSY

Research into the relationship between anthropogenic factors, the incident of infectious diseases and the evolutionary consequences has not been fully developed and this topic is still controversial. As Vøllestad points out, climate change leads to changes in species ranges and also often increases the prevalence and incidence of pathogens: "We know a lot about the direct effects of pathogens, but the evolutionary effects to the new host population are not at all well-known".

Although Vøllestad admits that the results from modelling are difficult to put to direct use: "Results based on this kind of research have to be made part of our common knowledge base and then used to inform decisions, but I would be happy if some of our results were expanded upon and used by other researchers".

The project could potentially bring important new perspectives to climate research in general. Firstly, the project will improve knowledge of the impacts of climate change on the various components of lake ecosystems. Secondly, it will quantify uncertainty in predictions, and thirdly, it will help develop robust management strategies.

BEYOND WINDERMERE

The research activities are now in the final stages and the team is developing a structured population model which will allow for continuous temporal variation in main parameters. Researchers hope this model will enable them to predict vital rates for the Windermere pike population under different climate change scenarios.

Although the project is almost finished, Vøllestad believes the study can be extended into genomics: "It would be very interesting to use third-generation sequencing technology to investigate the changes that have occurred at the genetic level. This would be a real challenge, but a very rewarding one".

INTELLIGENCE

MODELLING ECOSYSTEMS UNDER CLIMATE CHANGE: WINDERMERE AS A MODEL LAKE SYSTEM

OBJECTIVES

To develop separate statistical models to quantify each of the interactions in the Windermere food web, including possible demographic effects of rapid life-history evolution already detected in both the predator and prey fish populations. Then, parameter estimates from these models will be used as matrix entries in the community model. The refinement of the matrix approach will provide accurate predictions and uncertainty for the effects of global warming on temperate lake ecosystems in the decades ahead.

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Centre for Ecology and Hydrology (CEH), UK

Fresh Water Biological Association, UK

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Research Roundtable

Increasing food production sustainably, whilst protecting the ecosystems from which food sources are derived, is one of the grand challenges of our era. The Nordic Region has consistently produced innovations and generated knowledge which helps address the task. Here, *International Innovation* asks a range of stakeholders to identify the underlying factors for such excellence...

How is the Nordic Region leading the field in its approach to new environmental technologies and research, particularly in relation to food production and land and resource management? What can research from the region offer Europe as a whole?

Ronald Albers
(European Network of Environmental Research Organisations):

The Nordic Region has a history of enforcing strict environmental regulation while at the same time maintaining a high standard of living and a thriving economy. The Region has a high resource and energy efficiency and an effective and intensive agriculture. It is thereby the best proof that sustainability and economic development are not mutually exclusive. This represents a challenging example for the rest of the world to follow.

Dr Dr Christofer Troedsson
(Uni Environment):

Norway has, with its traditionally close connections to the oceans and as one of the major oil producing and aquaculture countries in the world, a special responsibility to monitor and understand how human explorations will affect the marine environment. These industries are also under tight environmental regulation by the Norwegian authorities. Norway has strong subsea technology knowledge, and with the integrated monitoring platforms being developed this can be transferred to other environments around Europe that are sensitive to human impacts.

Dr Hilde Bjørkhaug
(Centre for Rural Research):

It is very difficult to talk about a uniform Nordic Region regarding food production and resource management. Even though the Nordic countries share many cultural and political ideals, the policy regimes that agriculture is built on differ to a great extent. The Norwegian agricultural model is domestic-orientated and based on extensive economic support to farmers to sustain multiple goals in policy. At the other end of this scale is the Danish model that is export-orientated and production is adapted to global trade. The other Nordic countries find themselves between these two cases. There are also obvious differences between those Nordic counties that are members of the EU and those who are not due to domestic and CAP policies.

Norway has maintained quite comprehensive programmes for research on environment, agriculture and resource management, for national research but also encouraging collaboration with frontier research expertise internationally.

Professor Ann Norderhaug
(Norwegian Institute for Agricultural and Environmental Research):

An important component characterising research within this field in the Nordic countries is the trans-disciplinary and holistic approach, exemplified by our heathland project. Several European researchers are studying connections between grazing and biodiversity, grazed species and quality of milk and meat products, rural development and branded products etc. but very few are linking the connections in one project. Of course, it may be difficult to integrate too much in one project but at the same time it will be difficult to give correct advice and develop good measures without documenting and linking the most important connections.

Dr Magnar Forbord
(University Centre Dragvoll):

The Nordic Region has taken a strong lead in certain environmental technologies such as wind power and bioenergy. In Norway, the focus on environmental concern in agricultural research started in the 1970s, and protection of cultivated soil plays a central role in agricultural policy. Moreover, farmers must meet certain environmental requirements in farming in order to obtain subsidies.

Europe as a whole can learn from research in the Nordic Region on certain topics and the way research is implemented in society. Normally, there is close cooperation between research, authorities and users. Nordic countries like Finland and Norway have carried out a great deal of research on development and maintenance of rural communities; rural tourism is part of this.

Former Minister Lars Peder Brekk,
(Ministry of Agriculture and Food, Norway):

A sustainable and emission-friendly agriculture and food production have always held high political priority in Norway. The focus has been on sustainable use of available farm land, food safety and good animal health and welfare. Research has been an important instrument to obtain these objectives.

The need for knowledge about more efficient and productive food production will increase in a era of limited resources, population growth and climate change. In years to come, Nordic countries have to increase food production in order to meet the demand of a growing population. However, increased production should be achieved with minimal environmental impacts – a sustainable agricultural intensification. This is not possible without research-based knowledge. Therefore, research related to sustainable food production and more efficient use of land and available resource is given high priority in Norway and other Nordic countries.

However, a switch towards a more sustainable and environmentally-friendly agriculture and food production is not possible without a strong link and collaboration between policy makers, researchers, advisory services and farmers. In this area, Nordic countries hold an exceptional position regarding the short distance from research to implementation of new strategies and technologies.

Minister Lisbeth Berg-Hansen (Ministry of Fisheries and Coastal Affairs, Norway):

The Nordic Region as a whole is certainly a frontrunner in research and technology in the areas of sustainable resource management, sound coastal area management, and continuous improvement in waste management and energy efficiency. Norway is of course the biggest investor in research and technology in these fields, but Iceland is an important player in vessel technology and logistics development and Denmark is also very strong in fish processing. All countries have an outstanding record on byproduct handling, and are close to reaching zero waste levels from fish processing. In fact, these countries have managed to establish an entire new industry based on biological resources that were previously regarded as waste.

The regional cooperation among the Nordic countries is particularly interesting, involving both EU as well as non-EU Members. In the field of fisheries and aquaculture research this difference is a very dynamic element; it means that the Nordic research community is well informed about the technological challenges in EU, for example, in connection with revision of the Common Fisheries Policy, and it also represents a bridge for communicating new solutions, verified outside the EU system, into the community.

Arni Mathiesen (Food and Agriculture Organization):

A key strength of the Nordic Region lies in linking scientific research with management decisions, and in placing an emphasis on food safety and security. This, linked to efficiency in administration of both resource management systems and production systems, has been important. Another factor worth noting is an emphasis on increasing the value of the products and utilising an ever-larger share of the available resource using innovative new technologies and marketing skills.

Professor Nils Chr. Stenseth (University of Oslo):

Although the Nordic Region represents only a small proportion of the global population, it is among the most severely impacted by global climate change. Our institutions have recognised this as a challenge that will require new research and environmental technological approaches to address, particularly in relation to our continued stable food production and resource management. There is now increasing recognition in the European Community, but also globally, of the importance of transnational and interdisciplinary programmes to effectively research such global challenges. The Nordic Region has taken a leading role in this by making large multi-year pools of funding available, such as for the Nordic Centre of Excellence (NCoE) programme, which gave us an opportunity to build NorMER. Each NCoE is an international programme with a focus on continued stable food production (fisheries, Sami reindeer herding), land-use issues (managing tundra landscapes, social land-use studies), and resource management (biodiversity preservation), all within the Nordic Region. Such large funding schemes are rare, but extremely important for the type of large-scale efforts that can make a difference. We hope that our regional-based funding and research efforts to develop programmes that are independent of and parallel to the EU system will be an inspiration to other nations throughout Europe to support additional programmes.

Philippe Cury (Institute of Research for Development):

The oceans represent incredible opportunities for our development, for innovation and for finding new solutions to management of natural resources. With NorMER and other initiatives throughout Europe (Eur-Oceans consortium), a new platform that will bring together disciplines ranging from genes to ecosystems is emerging that can produce new knowledge. Such interdisciplinary approach will better articulate ideas, results, and new tools, and will respond in a more appropriate way to emerging challenges arising with global changes. This consilience is required to build scenarios of our future use of marine-based food in a global and shared perspective.

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