

***Aquaculture – An Industry in Growth
(HAVBRUK)
(2006-2015)***

Action Plan for 2009

*Vision:
Aquaculture – our most important growth industry*

Foreword

The programme *Aquaculture – An Industry in Growth (HAVBRUK)* continues the initiatives of previous aquaculture programmes and other aquaculture-related activities under the Research Council. The action plan for 2009 is a revised version of the action plan for 2008.

Tasks that will be given priority for 2009 have been indicated in *italics* in a box such as this.

The action plan, which is based on the HAVBRUK work programme, sets the course for the programme's current priorities, and is the guide for announcing funding opportunities for 2009. The following calls for proposals for research funding will be issued for 2009:

- Call for proposals for Researcher Projects and Knowledge-building Projects with User Involvement and for projects to enhance international cooperation (application deadline 4 June 2008, 12:00 pm)
- Call for proposals for (application deadline 3 September 2008, 12:00 pm)
 - User-driven Innovation Projects (BIP)
 - Land/sea area use in coastal areas – a joint call issued by the HAVBRUK programme, the NATURNÆRING programme and the HAVKYST programme in cooperation with the FHF
- Call for proposals for Support for Events for 2008 (open-ended deadline)

Oslo, 10 April 2008

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0. Summary

The research programme *Aquaculture – An Industry in Growth (HAVBRUK)* is one of seven large-scale programmes established in 2004. The primary objectives of the programme are to cultivate knowledge as the basis of a profitable and value-creating aquaculture industry based on sustainable, market-oriented production, and to ensure that research circles and the Norwegian aquaculture industry develop knowledge of a high international standard in areas crucial to the industry's advancement. As a large-scale programme, it seeks to enhance knowledge in a long-term national context by helping to promote innovation and value creation or by generating knowledge that will help to solve major challenges within society. The programme is designed to promote links between basic research, applied research and innovation activity, across disciplines and sectors, through the strategic implementation of different funding schemes.

The HAVBRUK programme is the Research Council's most important funding instrument for the aquaculture industry and encompasses the entire value chain for the production of aquatic organisms, including the supplier industry in the value chain. The programme is an integral part of the Research Council's efforts to strengthen research in the government priority areas of oceans and food, which also include other programmes and instruments. Cooperation with such programmes and instruments therefore plays an important role in several areas of relevance to aquaculture, such as research on markets and food processing, which is primarily covered by *the Food Programme: Norwegian Food from Sea and Land (MATPROGRAMMET)*, and research on society, which is primarily covered by the *Programme for Nature-based Industrial Development (NATURNÆRING)*, both of which are under the Division for Innovation. The HAVBRUK programme actively encourages aquaculture-related research in these areas.

The HAVBRUK programme is designed to facilitate strategic basic research in a number of areas within biology, technology and ecology. Where more discipline-oriented basic research targeted toward aquaculture is concerned, cooperation with appropriate programmes and instruments under the Division for Science will be vital. In this way the programme seeks to promote links and collaboration between aquaculture-related activities under the various divisions. Collaboration with other national sources of funding, particularly Innovation Norway and the Fishery and Aquaculture Industry Research Fund (FHF), has also been established in order to encourage international cooperation in aquaculture research.

The action plan, which is based on the HAVBRUK work programme, sets the course for the programme's current priorities for the research community, and is the guide for announcing funding opportunities.

The following sub-programmes will be given priority in the HAVBRUK action plan for 2009:

- Strategic areas of focus for competitive advantages and wealth creation
- Strategic basic research
- Sustainability
- Production of salmonids
- Production of other species
- A knowledge culture and an aquaculture-based innovation system

The Ministry of Fisheries and Coastal Affairs, the Ministry of Agriculture and Food and the Norwegian Fund for Research and Innovation are the primary sources of allocations to the HAVBRUK programme. The Fishery and Aquaculture Industry Research Fund (FHF) and Innovation Norway also contribute with co-financing of projects.

The action plan is revised on an annual basis.

1. Background

Norwegian aquaculture contributes substantially to upholding value creation with respect to exports, employment, and settlement patterns in coastal areas. A supplemental industry just 30 years ago, Norwegian aquaculture has emerged as the world's leading exporter of salmon and salmon-trout. At present, Norway exports salmon products to over 100 countries, while helping to create many jobs in Norway and other nations, especially in the EU.

Aquaculture is a young industry with its origins in the primary industries. It is a knowledge-based industry and is expected to remain a key industry for Norway in the long term as well. But the industry finds itself in a highly competitive situation in which limited access to large markets combines with increasing competition from other fish-farming nations to make it difficult for companies to maintain sufficient profitability. Despite the facts that the production costs of farmed salmonids have been greatly reduced, production levels are at an all-time high, and seafood is popular in many markets, Norway's aquaculture industry has nevertheless posted negative overall earnings at times and the contribution of production in the value chain to the gross domestic product (GDP) has declined in recent years. The industry's ripple effects, however, have shown significant increase in recent years, so that as a whole the contribution to GDP by the overall aquaculture value chain has remained virtually unchanged.¹

It is essential to acquire basic knowledge in a number of areas in order to develop strategic expertise that will result in competitive advantages and form a basis for value creation. Long-term, targeted R&D investment combined with innovation at every stage will be necessary if Norwegian aquaculture is to succeed in realising its true potential. The industry must devise initiatives to strengthen its competitiveness, and the foundation must be laid for an economic, social and political framework that will ensure this industry's future. The Research Council of Norway seeks to foster these developments; the establishment of the large-scale research programme *Aquaculture – An Industry in Growth (HAVBRUK)* actively creates a framework for extensive cooperation with the aquaculture industry, its equipment suppliers, researchers and the authorities.²

¹ “Betydningen av fiskeri- og havbruksnæringen for Norge – en ringvirkingsanalyse” (An analysis of spreading effects from the fisheries and aquaculture sector in Norway). Updated in 2002. Norwegian only

² *Aquaculture – An Industry in Growth (HAVBRUK)* is one of seven large-scale programmes established in 2004 and administered by the Research Council of Norway. The large-scale programmes play an important role in efforts to fulfil national research policy priorities. These programmes seek to enhance knowledge in a long-term national context by helping to promote innovation and value creation or by generating knowledge that will help to solve major challenges within society. The large-scale programmes are designed to promote links between basic research, applied research and innovation activity, across disciplines and sectors, through the strategic implementation of different funding schemes.

The HAVBRUK programme is the Research Council's most important funding instrument for the aquaculture industry and encompasses the entire value chain for the production of aquatic organisms, including the supplier industry in the value chain. The programme is intended to actively motivate research in these areas, particularly research on the production phase, as well as to promote links between basic research, applied research and innovation activity, across disciplines and sectors, through the strategic implementation of different funding schemes. Research carried out under other programmes under the Research Council may have direct relevance to aquaculture, such as research on markets, society, framework conditions and food safety. Relevant programmes in this context include *the Food Programme: Norwegian Food from Sea and Land (MATPROGRAMMET)* and *the Programme for Nature-based Industrial Development (NATURNÆRING)*. When joint calls for proposals and joint projects involving multiple programmes may prove practical, the HAVBRUK programme board will take the initiative to launch such activities. It is crucial that the programme has a constructive interface with other appropriate programmes under and instruments employed by the Research Council's Division for Innovation and Division for Science, as well as with Innovation Norway and the Fishery and Aquaculture Industry Research Fund (FHF).

The HAVBRUK work programme applies for the duration of the programme period, 2006-2015, but may be revised underway. A separate action plan is drawn up based on the work programme, setting the course for the programme's current priorities for research and providing the basis for funding announcements. The action plan is a key tool for communication between the HAVBRUK programme board and the governing bodies of the Research Council, with regard to both the basis for budget proposals and expected results. It is revised on an annual basis. The action plan must not employ resources beyond the financial framework allocated to the programme and must specify priorities that will be applicable if proposed budget increases are approved.

2. Programme objectives

Vision:
Aquaculture – our most important growth industry

Primary objectives

- To cultivate knowledge as the basis of a profitable and value-creating aquaculture industry based on sustainable, market-oriented production.
- To ensure that research circles and the Norwegian aquaculture industry develop knowledge of a high international standard in areas crucial to the industry's advancement.

Secondary objectives

- To generate knowledge for developing value creation and profitability in the salmon industry, based on sustainable, market-oriented production at every stage.

- To facilitate knowledge for developing value-creating, profitable business activities at all stages, founded on at least one new species in the course of the programme period, and in addition obtain knowledge about certain selected species with a view to commercialisation.
- To gain knowledge that provides a basis for developing all production and products within an acceptable framework with respect to sustainability, the environment, animal welfare and food safety.
- To secure long-term, strategic knowledge enhancement of a high international standard throughout the research community, industry and government administration.

Target group

The HAVBRUK programme encompasses the production of salmonids and other species through the entire value chain, including parts of catch-based aquaculture and sea ranching and the market for lightly processed products.³ The programme is targeted toward all aspects of the aquaculture industry, including the supplier industry and various customer groups, research institutes, universities and university colleges. The authorities are also an important target group for the programme, as they are responsible for resource management and for laying the foundation for industrial development within the sector.

Instruments employed

The HAVBRUK programme is designed to foster the development of basic expertise, exploit the nation's resources in a responsible fashion and facilitate knowledge production and innovation throughout the entire value chain. This will be achieved using a variety of different instruments. In many cases, cross-disciplinary and cross-institutional projects will be called for. Key funding instruments employed under the programme are:

- Knowledge-building instruments
 - Researcher Projects
 - Knowledge-building Projects with User Involvement (KMB)
- User-driven instruments
 - User-driven Innovation Projects (BIP)

Knowledge-building instruments (Researcher Projects and KMB) are targeted toward research institutions to assist researchers in the effort to meet the long-term knowledge needs of industry and the public authorities. In special cases the creation of high-level scientific hubs incorporating, for example, collaboration across institutional boundaries and knowledge platforms, may be called for. Key areas in this context are strategic basic research and strategic areas of focus for competitive advantages and value creation. It may also be of interest to draw from the expertise of various disciplines at universities and university colleges by linking specific research problems with top-quality research groups in order to ensure that the standard of the strategic basic research is of a high enough calibre.

Recruitment in the form of doctoral and post-doctoral research fellowships is a crucial task for the programme. International researcher mobility is essential, and includes Norwegian researchers and fellowship-holders spending time at research institutions abroad as well

³ The market for processed products lies within the scope of *the Food Programme: Norwegian Food from Sea and Land (MATPROGRAMMET)*.

international researchers participating in Norwegian research communities. Doctoral and post-doctoral fellows should arrange a stay of at least six months at an international research institution in the course of the fellowship period. Fellowships under the HAVBRUK programme will primarily be affiliated with the projects.

Projects will generally have a timeframe of three years, which may be extended in cases. For 2009 the HAVBRUK programme board is considering allocating funding to one or two projects for outstanding younger researchers in the early stages of their career, in connection with Sub-programme 2: Strategic basic research.

Funding may also be sought for basic research and recruitment in marine research projects under programmes under the Division for Science.

User-driven instruments (BIP) are targeted toward industry. Knowledge-building is an essential component of user-driven projects as well. Projects that involve collaboration between several companies as well as with the research community are of particular interest to the programme, but funding may also be provided for projects led by individual companies. Projects may have a timeframe of maximum three years. In addition, the SkatteFUNN tax deduction scheme may contribute financing for user-driven activities.

Species

Given the limited financial framework of the programme, species-related research activities must be given priority, and the programme is intended to include activities related to several species with potential for commercialisation. Among the salmonids, salmon will be given the highest priority. Among the new species, cod will be given special priority; activities related to halibut, mussels and scallops are also of interest. The programme may also allocate funding to research projects on other species where industry is involved.

3. Analysis of status and challenges

Chapter 3: Analysis of status and challenges is included as Attachment 2 to the action plan for 2009.

4. Programme structure, priority research areas, and tactics for achieving good national distribution of tasks and multidisciplinary cooperation

4.1 Programme structure and priority research areas

The HAVBRUK programme consists of six sub-programmes:

- Strategic areas of focus for competitive advantages and wealth creation
- Strategic basic research
- Sustainability
- Production of salmonids

- Production of other species
- A knowledge culture and an aquaculture-based innovation system

4.1.0 Introduction – budgetary

To achieve the programme objectives described in Chapter 2, the HAVBRUK programme will conduct:

- Basic research on topics and species relevant to the advancement of the aquaculture industry.
- Research to enhance knowledge about the environment, animal welfare and food safety.
- Research targeted toward the development of knowledge and problem-solving measures for use in the value chain for the production of salmonids and other species.

Basic research on topics and species relevant to the advancement of the aquaculture industry is described in greater detail under Sub-programme 1: Strategic areas of focus for competitive advantages and wealth creation, and Sub-programme 2: Strategic basic research. In accordance with the budget specifications in this action plan, 40-60 per cent of total funding will be allocated to these two sub-programmes. In the case of a zero-growth budget in 2009, approximately NOK 11.5 million is expected to be available for new projects.

Research to enhance knowledge about the environment, animal welfare and food safety is described in greater detail under Sub-programme 3: Sustainability. In the case of a zero growth budget in 2009, approximately NOK 9 million is expected to be available for new projects under this sub-programme.

Research targeted toward the development of knowledge and problem-solving measures for use in the value chain for the production of salmonids and other species is described in greater detail under Sub-programme 4: Production of salmonids, and Sub-programme 5: Production of other species. In the case of a zero-growth budget in 2009, approximately NOK 9.5 million (NOK 4 million for salmonids and NOK 5.5 million for other species) is expected to be made available for Researcher Projects and Knowledge-building Projects with User Involvement under these sub-programmes. Additional funding may be allocated to User-driven Innovation Projects (BIP). Given zero-growth, approximately NOK 5 million is expected to be made available for new BIP projects.

Possible budget increase

The Research Council's Focus on the Northern Areas initiative provides an important area of focus for the HAVBRUK programme, and if its budget is increased, the programme will boost its level of activity in this area. A specific plan has been created for aquaculture research within the framework of the initiative and is available as an attachment to this action plan. Research activities focusing on the Northern Areas are integrated into the existing sub-programmes under the HAVBRUK programme.

4.1.1 Strategic areas of focus for competitive advantages and wealth creation

The focus of this sub-programme is on building strategic expertise to provide vital competitive advantages and enhance the basis for value creation. This will be accomplished by creating high-level scientific hubs and knowledge platforms through cross-institutional projects. Grant proposals involving knowledge platforms will be expected to incorporate collaboration across institutional and disciplinary boundaries, both nationally and

internationally, with a view to developing the best possible expertise. Projects should have a timeframe of maximum four years, and may employ budgetary parameters averaging NOK 4-5 million from the Research Council per year. Four knowledge platforms have been established to date: *Alternative feed ingredients and nutrition; Normal and abnormal development; Effective and sustainable technology; Scientific basis for vaccine development.* No funding announcements for new knowledge platforms will be issued for 2009.

4.1.2 Strategic basic research

Objective: To secure long-term, strategic knowledge enhancement of a high international standard throughout the research community, industry and government administration.

The term “strategic basic research” refers to basic research on topics and species relevant to the continued development of the aquaculture industry. The objective of strategic basic research is to enhance the overall level of understanding of a topic or species, while creating a foundation for future application of this knowledge, either directly or through applied research.

Sub-programme 2: Strategic basic research encompasses the following areas:

- Production biology and environmental conditions
- Health
- Alternative feed ingredients and nutritional requirements
- Genetics and selective breeding
- Production technology
- Healthy food – product quality

Researcher Projects are the key funding instrument employed under this sub-programme. Grant applications should incorporate plans for national and international cooperation, with an eye to developing dynamic knowledge communities, ensuring the dissemination of knowledge, and avoiding the unnecessary development of parallel expertise. Projects that include a researcher recruitment component and the development and implementation of new techniques and methods (in biotechnology, nanotechnology, materials technology and ICT) will be viewed in a favourable light. Assuming a zero-growth budget, NOK 11.5 million in funding is expected to be made available for new projects under this sub-programme (subject to change).

The bulleted points in the boxes below are areas that will be given priority in 2009. The bulleted points that are not in a box will not be given priority in 2009 either because research is already ongoing in these fields or for other reasons.

Project for outstanding young investigators

For 2009 the HAVBRUK programme board will consider allocating funding to one or two projects for outstanding younger researchers in the early stages of their career.

Project funding of this type is intended to give candidates a sound basis for achieving international excellence and acquiring good research management skills. To be eligible, the applicant must have completed a doctoral degree and must be able to document scientific production subsequent to degree completion that demonstrates his or her potential to conduct research of high international calibre. As of the deadline expiry date of 4 June 2008, no more than six years may have passed since the applicant defended his or her doctoral thesis. If the

applicant has been granted any formal leaves of absence in the interim between thesis defence and the stipulated application deadline, the time spent on leave will be subtracted from the total when calculating the relevant time period. Grant applications must be submitted by a university or university college or an independent research institute; the institution itself will be defined as Project Owner. Each institution may submit only one grant application. To encourage researchers to establish or further develop their own research groups, allocations of up to NOK 2 million per year per project for maximum four years may be sought by individual researchers who demonstrate professional excellence. Grant proposals may be submitted for projects that lie within the entire scientific scope of Sub-programme 2: Strategic basic research and Sub-programme 3: Sustainability. The candidate's professional qualifications and potential to achieve high international standing, as well as the project's scientific merit, benefit to society and relevance will be decisive criteria during the application review process.

Production biology and environmental conditions

- *Generate basic knowledge about the normal formation, differentiation, development and functions of major organ systems throughout critical stages of life and in interaction with the environment to ensure normal development in intensive production.*
- *Explain how nutrition and physiological status interact with environmental factors in regulating growth and puberty (onset of initial sexual maturation), and refine methods for controlling growth, puberty and spawning time as a basis for optimising the production environment.*
- *Further develop methods for monitoring the quality of fry, fingerlings and smolt that give adequate consideration to important conditions for animal well-being and place priority on criteria for predicting future performance in production.*

Health

- *Acquire basic knowledge to identify potential infectious agents that contribute to the development of costly diseases such as heart and skeletal muscle inflammation (HSMI) and cardiomyopathy syndrome (CMS).*
 - *Procure basic knowledge about spreading mechanisms for relevant, costly infectious diseases, including molecular characteristics of agents.*
 - *Generate basic knowledge about the effects of environmental factors and nutrition on the development of infectious and non-infectious diseases.*
 - *Gain basic knowledge about the biological processes and development of production-fish parasites that are essential to describing their interactions with host organisms and the surrounding environment.*
- Procure basic knowledge of the immune system of pertinent production species that is significant to protective immune responses.
 - Acquire basic knowledge about characteristics of currently problematic infectious agents and their host organisms pertaining to disease development, with special emphasis on costly viral and bacterial diseases.

Alternative feed ingredients and nutritional requirements

- *Enhance basic knowledge of species' nutritional requirements at various stages of development and under different environmental conditions, and develop new methods in systems biology for studying the effects of feed on a species.*

- *Generate basic knowledge to facilitate utilisation of alternative feed ingredients, including development of fish feed supplements for production species of interest at various stages of development.*

- Learn how to increase the utilisation of marine feed ingredients (bioproducts, krill, plankton).
- Acquire expertise in the efficient utilisation of the pigments in pertinent species, through biological utilisation and through measures that preserve the pigments during raising, slaughter, processing and storage.
- Determine the tolerance levels of various production species to relevant anti-nutrients and potentially toxic feed components.
- Optimise feed composition throughout the life cycle and for different environmental conditions in various production species.

Genetics and selective breeding

- *Gain knowledge about genetic and phenotypical variation, heritability, genetic correlations and the economic value of key characteristics in relevant fish species.*
- *Refine molecular-genetic methods combined with traditional selective breeding.*

- Develop statistical/biometric methods in connection with molecular-genetic information and strategies for implementing non-additive genetic effects.
- Clarify the significance in breeding programmes of non-destructive methods of measuring quality, disease resistance, fish welfare, feed utilisation and utilisation of new feed ingredients.
- Examine possibilities relating to the development of new selection methods combined with traditional breeding, as well as possibilities of selecting for characteristics from wild salmon for the breeding material.

Production technology

- *Acquire basic knowledge to develop production designs that meet future requirements for safeguarding animal welfare and the environment and which also minimise escapes.*
- *Develop production processes and technology to improve the quality of fry production for marine species.*

- Generate knowledge for rationalising salmon smolt production through improvement of routines, processes and technology.
- Provide technology that improves and safeguards water quality and that makes it possible to minimise consumption of fresh water.

Healthy food – product quality

Research on selected topics within this area will be carried out in collaboration with the Food Programme. Cf. call for proposals from the R&D programme Norwegian Food from Sea and Land (MATPROGRAMMET). Please refer to the report “Trygg sjømat – risikofaktorer i verdikjedene fra fjord til bord for villfanget og oppdrettet sjømat. En utredning om kunnskapsbehovet” (Safe seafood – risk factors along the value chains from fjord to table for wild and farmed seafood. A report on knowledge needs, Norwegian only).

- *Cultivate basic knowledge of how genetic and physiological characteristics, different production regimes and feed composition can be utilised to achieve desired product*

quality of production species, with particular focus on ensuring optimal colour and nutritional quality, and avoiding problems with gaping, soft flesh and fat release.

- *Gain basic knowledge about factors during production, slaughter, transport, handling and processing that affect sensory and nutritional quality, characteristics for further processing and shelf life of the finished food products.*

- Ensure that knowledge development in the aquaculture industry is based on market demands for product quality.

4.1.3 Sustainability

Objective: To gain knowledge that provides a basis for developing all production and products within an acceptable framework with respect to sustainability, the environment, animal welfare and food safety.

The following areas will be given priority under this sub-programme:

- Environmental and ecological impacts
- Safe food and safe feed
- Animal welfare

This sub-programme encompasses both basic research and research targeted at solving specific problems. Up-to-date knowledge about environmental issues, animal welfare and food safety is essential for providing the authorities with a basis on which to lay down key framework considerations for the sound development of the aquaculture industry. Researcher Projects and Knowledge-building Projects with User Involvement (KMB) are key funding instruments employed under this sub-programme. Projects, particularly larger-scale projects, should incorporate cross-disciplinary and cross-institutional collaboration, as well as recruitment and knowledge dissemination activities. Cooperation with other programmes under the Research Council also plays an important role in several areas. Relevant programmes in this context include the Food Programme (food safety), the NATURNÆRING programme (framework conditions), and the HAVKYST programme (environmental issues).

In the case of a zero growth budget in 2009, approximately NOK 9 million in funding is expected to be available for new projects under this sub-programme (subject to change).

The bulleted points in the boxes below are areas that will be given priority in 2009. Due to ongoing research or other factors, the bulleted points that are not in a box will not be given priority in 2009.

Environmental and ecological impacts

- *Gain knowledge about the spread of parasites and infectious diseases between production species and wild stocks, including knowledge about relevant modelling tools and risk management measures.*
- *Generate knowledge about ecological and genetic interactions between production species and wild stocks, including species used in sea ranching, and about measures to counteract undesirable impacts.*
- *Cultivate knowledge about potential environmental and ecological impacts of discharges from aquaculture operations.*

- Cultivate knowledge as to how contaminants enter the environment, how they are broken down and where they settle in the food chain.
- Lower the risk of the spread of contagion to wild stocks and to other production organisms.
- Gain knowledge needed for measuring and assessing effects of sea ranching.

Safe seafood and safe feed

Research on selected topics within this area will be carried out in collaboration with the Food Programme. Cf. call for proposals. Please refer to the report “Trygg sjømat – risikofaktorer i verdikjedene fra fjord til bord for villfanget og oppdrettet sjømat. En utredning om kunnskapsbehovet” (Safe seafood – risk factors along the value chains from fjord to table for wild and farmed seafood. A report on knowledge needs, Norwegian only).

- *Acquire knowledge about contaminants as risk factors, with focus on environmentally hazardous substances, pesticides and heavy metals within the perspective of the entire food value chain.*
- *Procure knowledge about interactions between undesirable substances and nutritional factors in seafood.*

- Develop new methods for decontaminating feed, water and nutrients with regard to the contaminants above.
- Generate knowledge about infectious agents (especially zoonotic agents) that affect human health.
- Cultivate knowledge regarding potential negative effects of genetically modified (GMO) materials in feed.

Animal welfare

- *Develop methods and objective criteria for assessing the well-being of production fish, including negative and positive welfare indicators, as the basis for operational indicators suited to commercial facilities.*
- *Generate basic knowledge about the general behaviour and behavioural needs of production fish, and about the connection between environmental factors, stress, coping strategies, behaviour, health and welfare in intensive production.*

- Procure knowledge about the effects of starvation, handling, and methods of transport and slaughter on behaviour, stress and product quality.

4.1.4 Production of salmonids

Objective: To generate knowledge for developing value creation and profitability in the salmon industry, based on sustainable, market-oriented production at every stage.

Research activities under this sub-programme are targeted toward the development of problem-solving measures for use in the production and distribution chain for salmonids and/or by the supply industry. This may involve issues relating to health, production, environmental conditions, feed, nutrition and feeding technology, facilities and equipment, transport of live materials, logistics, distribution and packaging, and traceability.

Multidisciplinary research on various stages in the production and distribution chain and involving extensive knowledge transfer is encouraged. Knowledge-building Projects with User Involvement (KMB) and Researcher Projects are the key funding instruments employed under this sub-programme.

The Food Programme and the NATURNÆRING programme each have a general responsibility to provide funding for research on market access and how markets function, and to develop knowledge to support industrial development, trade policy and land/sea use policy. The HAVBRUK programme will also carry out research in these areas in collaboration with the two programmes. Priority will be given to generating knowledge of consumer trends, structural changes in the market, competitive conditions, distribution and sales, logistics, organisation, integration and forms of cooperation.

The HAVBRUK programme has the primary responsibility for procuring and applying knowledge regarding lightly processed seafood products throughout the value chain.

In the case of a zero growth budget in 2009, approximately NOK 4.5 million in funding is expected to be available for new projects under this sub-programme (subject to change).

Priority will be given to the following topics under this sub-programme:

- *Reducing animal losses throughout the production chain*
- *Optimising production design and environmental conditions*
- *Market-oriented production*

Grant proposals for projects related to these three topics may address issues relating to: health, including descriptive epidemiology; production biology and environmental conditions; production technology, sea and land-based facilities, including recirculation facilities, and equipment; feed, nutrition and feeding technology; transport of live materials; product quality; traceability; and logistics, distribution and packaging.

4.1.5 Production of other species

Objective: To facilitate knowledge for developing value-creating, profitable business activities at all stages, founded on at least one new species in the course of the programme period, and in addition obtain knowledge about certain selected species with a view to commercialisation.

Research activities under this sub-programme are targeted toward the development of problem-solving measures for use in the production and distribution chain for species other than salmonids⁴ and/or by the supply industry. This may involve issues relating to health, production, environmental conditions, technology, feed, nutrition and feeding technology, transport of live materials, logistics, distribution and packaging, and traceability. Multidisciplinary research on various stages in the production and distribution chain and involving extensive knowledge transfer is encouraged. Knowledge-building Projects with User Involvement (KMB) and Researcher Projects are the key funding instruments employed under this sub-programme.

The Food Programme and the NATURNÆRING programme each have a general responsibility to provide funding for research on market access and how markets function, and to develop knowledge to support industrial development, trade policy and land/sea use policy. The HAVBRUK programme will also carry out research in these areas in collaboration with the two programmes. Priority will be given to generating knowledge of

⁴ Cf. description of species, HAVBRUK action plan for 2009, page 7.

consumer trends, structural changes in the market, competitive conditions, distribution and sales, logistics, organisation, integration and forms of cooperation.

The HAVBRUK programme has the primary responsibility for procuring and applying knowledge regarding lightly processed seafood products throughout the value chain.

In the case of a zero growth budget in 2009, approximately NOK 5.5 million in funding is expected to be available for new projects under this sub-programme (subject to change).

The focus of this sub-programme is on cod and other species. Research on cod will be based on the Joint Plan for Cod initiative (revised in April 2006) and on the HAVBRUK action plan for 2009.

Priority will be given to the following topics in this sub-programme:

- *Cod:*
 - Methods and technology for automating and industrialising production of fry and fingerlings*
 - Water quality and recirculation technology in marine fry production*
 - Sexual maturation in relation to economically efficient and environment-friendly production*
 - Control of parasites and diseases*
 - Feed and nutrition*
 - Product development, feedstuff utilisation and product quality*
 - Developing unobtrusive, cost-effective and accurate systems for weighing, counting and measuring (at the individual level)*
- *Other species: higher survival rates and greater efficiency in the production chain*

4.1.6 A knowledge culture and an aquaculture-based innovation system

The aquaculture industry is rooted in research findings and the experience-based knowledge of the industry players, and interaction between the parties involved in the industry must be increased. The industry must become characterised by an awareness of and established practice for using research toward both continual enhancement and greater innovation, while researchers need to be able to seek inspiration and expertise from industry. By employing various instruments, such as providing support for seminars, establishing meeting places and implementing other dissemination measures, the HAVBRUK programme will facilitate the exchange of knowledge between the research establishment, industry and the government administration to help to create a knowledge culture and an aquaculture-based innovation system. Cooperation with Innovation Norway, the Fishery and Aquaculture Industry Research Fund (FHF) and regional authorities will play an important role in this context.

4.1.7. User-driven Innovation Projects (BIP)

User-driven Innovation Projects (BIP) are targeted toward industry. Knowledge-building is an essential component of user-driven projects as well. Projects that involve collaboration between several companies as well as with the research community are of particular interest to the programme, but funding may also be provided for projects submitted by individual companies. Projects may have a timeframe of maximum three years. The funding allocated to User-driven Innovation Projects will generally be a maximum of 30 per cent of overall project

costs. Applicants may seek additional public sector funding under the SkatteFUNN tax deduction scheme.

User-driven Innovation Projects may address all the topics and thematic priority areas encompassed by the HAVBRUK action plan. In the case of a zero-growth budget, approximately NOK 5 million in funding is expected to be available for new User-driven Innovation Projects (subject to change). The HAVBRUK programme collaborates with the Food Programme with regard to research projects on markets and food safety and with the NATURNÆRING programme with regard to research projects on industry development and policy design.

4.1.8 Enhancing international research cooperation

As part of the effort to enhance international research cooperation, the HAVBRUK programme will allocate funding in the form of Project Establishment Support for international projects, Personal Visiting Researcher Grants and Personal Overseas Research Grants. Special priority will be given to collaboration with researchers in the USA, Canada, Russia and China. A total of NOK 1.5 million has been set aside for this purpose.

4.1.9 Joint call for proposals on land/sea use in coastal areas

The use of land and sea area in coastal areas is increasing. Established industries, new industries, and societal and recreational interests must work together to ensure that land and sea area is used in a fashion that safeguards resources, pays adequate attention to environmental and climate considerations, enhances predictability and promotes industrial development. This creates a greater need for a cohesive, cross-disciplinary effort to generate knowledge that will encourage value creation and other social considerations in coastal areas and at sea.

A separate call for proposals will be issued jointly by the HAVBRUK programme, the NATURNÆRING programme and the HAVKYST programme. The budgetary parameters for this call for proposals are NOK 4-5 million per year over a period of three years. Priority will be given to grant proposals that incorporate a multidisciplinary approach involving participation of research groups in biology, technology, social science and economics. Collaboration between industry organisations, companies, the government administration and the FHF is essential. Funding will be allocated to one to two projects.

Projects will be assessed on the basis of scientific merit, benefit to society and relevance. Grant applications will be sent to external referees for scientific review. A group comprising representatives from the programme boards involved in the call for proposals is responsible for final processing of grant applications.

4.2 Grant applications and strategy for allocation of research funding

4.2.1 Grant applications

Researcher Projects and Knowledge-building Projects with User Involvement (KMB)

Applicants are responsible for specifying the HAVBRUK sub-programme and topic for which funding is being sought in the grant application. (For example: HAVBRUK/Sustainability/Environmental and ecological impacts.) Applicants should only list partners that have a role specified in the project description in the grant application. All grant applications, with the exception of proposals for User-driven Innovation Projects (BIP),

must be submitted in English. Grant applications for BIP must be submitted in Norwegian. For applications submitted in English, the project title, project summary and overall objectives must also be submitted in Norwegian as an attachment to the application.

User-driven Innovation Projects (BIP)

A separate call for proposals will be issued for User-driven Innovation Projects for 2009 with the deadline of 3 September 2008, 12:00 pm. Grant proposals for BIP may address any topic within the scope of the programme. Grant applications for BIP should preferably be submitted in Norwegian.

4.2.2 Strategy for allocation of research funding

In order to ensure the highest possible quality of the research activities, funding for both knowledge-building and user-driven projects will be awarded on a competitive basis.

Funding for research projects will be allocated on the basis of the relevance of grant proposals relative to the programme's primary and secondary objectives and benefit relative to the industry's short and long-term needs. Scientific merit is a requirement for all programme activities, and grant proposals demonstrating high scientific merit will be given priority during the application assessment process. Grant applications will be sent to external referees for scientific review. The relevance and benefit of research projects will be assessed by the HAVBRUK programme board in collaboration with the Research Council administration.

The HAVBRUK programme has defined objectives regarding the incorporation of a recruitment component, multidisciplinary perspectives, issues relating to the Focus on the Northern Areas initiative, as well as national and international cooperation into research projects. In cases where such objectives will serve to enhance the scientific merit, relevance and benefit to society of the project, applications that include these components will be given priority when funding is awarded. Collaboration with researchers in North America is given special focus in the context of international cooperation.

During the application assessment process consideration will be given to the relevance of the grant proposals relative to ongoing projects under the HAVBRUK programme and in other contexts.

A project manager may submit only one grant application to each sub-programme of the HAVBRUK programme.

In areas in which specific R&D plans have been devised, these will form the basis for research activities together with the HAVBRUK action plan for 2009. The following plans have been issued:

- *Production of cod. Joint Plan for Cod initiative (revised in April 2006). Research Council of Norway, Innovation Norway and the industry*
- *Action plan for R&D efforts in feed resources for aquaculture*
- *Health and disease problems in Norwegian aquaculture production species*
- *Possibilities and problems related to selective breeding of relevant marine species*
- *Research needs in the field of animal welfare in Norway*
- *Focus on the Northern Areas in the HAVBRUK programme – Attachment 3 to the action plan*

- “Trygg sjømat – risikofaktorer i verdikjedene fra fjord til bord for villfanget og oppdrettet sjømat. En utredning om kunnskapsbehovet” (*Safe seafood – risk factors along the value chains from fjord to table for wild and farmed seafood. A report on knowledge needs, Norwegian only*).

4.3 Boundaries in relation to and cooperation with other programmes and instruments

The Food Programme: Norwegian Food from Sea and Land (MATPROGRAMMET)

This programme is targeted toward industry and the public authorities, and encompasses the entire value chain, from consumer to primary agricultural and marine production, including market research but excluding research on topics covered by the HAVBRUK programme. Good synergies can be created between the Food Programme and the HAVBRUK programme in several areas, such as research on markets and food safety.

Programme for Nature-based Industrial Development (NATURNÆRING)

This programme is responsible for research on trade policy and public instruments for agriculture, fisheries and aquaculture, including research on international framework conditions, and land area and environmental management. Aquaculture-related research in these areas will primarily be conducted in cooperation with the HAVBRUK programme.

The Oceans and Coastal Areas (HAVKYST)

This programme promotes research on the marine environment to provide a foundation for management of marine resources. Topics such as new feed ingredients, safe feed resources and algae problems are covered by the HAVBRUK programme.

Maritime Activities and Offshore Operations (MAROFF)

Under this programme offshore operations and maritime activities are defined as activities designed to support other activities on and below the ocean surface. Thus, in addition to research programmes relating directly to the petroleum sector, this programme will have certain elements in common with the HAVBRUK programme.

Commercialisation of R&D results (FORNY)

The objective of the FORNY programme is to increase value creation in Norway by commercialising research-based business ideas with considerable market potential. The programme is primarily concerned with knowledge-building research activities.

National Programme for Research in Functional Genomics (FUGE)

One objective of this programme is to promote the establishment of national and regional models of cooperation that enable industry to utilise findings from research in functional genomics at universities and independent research institutes. The FUGE programme encompasses basic research (including bioinformatics) and marine and medical research.

Funding Programme for Regional R&D and Innovation, 2007-2010 (VRI)

Through the VRI programme the Research Council places special focus on research and innovation in Norwegian regions. The primary objective of the VRI programme is to promote innovation, knowledge development and value creation through regional collaboration and to strengthen R&D efforts in and for the regions. The VRI programme is a national programme and will initially span a period of 10 years (2007-2017). The programme is intended to

safeguard regional priorities, needs and competitive advantages as well as national strategies for R&D and innovation.

Other large-scale programmes

Modern biotechnology offers knowledge and methodology applicable to a number of aquaculture areas, such as selective breeding, fish health, feed, processing methods, traceability and environmental monitoring. Around the world, much effort is being invested into researching new vistas and materials through nanotechnology. The introduction of new construction materials for facilities, nets and packaging, as well as vaccines, sensors and catalysts, could greatly benefit the aquaculture sector. Emerging trends in aquaculture point to increasing use of ICT; new solutions and products from the ICT sphere may lead to further development in areas such as control and monitoring equipment, surveillance, modelling, biomass estimation and feed data. Another key task will be to promote cooperation with other large-scale programmes, both to incorporate new knowledge into the field of aquaculture and to integrate aquaculture's needs into the large-scale programmes and the relevant knowledge and technology platforms that exist or are being established. Relevant programmes in this context are the programmes on Functional Genomics (FUGE), Nanotechnology and New Materials (NANOMAT), and Core Competence and Value Creation in ICT (VERDIKT). Findings from research on Norway's petroleum resources conducted under the PETROMAKS programme may also be of relevance to the aquaculture industry.

User-driven Research-based Innovation (BIA)

This programme focuses on research-based innovation and is targeted toward knowledge-intensive trade and industry and cooperating R&D communities. The primary objective of the programme is to enhance the ability and the will of Norwegian trade and industry to achieve knowledge-based innovation of international calibre. Research-based innovation projects under the programme are not confined to particular thematic areas or branches of industry, and are based on applicants' own strategies and priorities.

Programmes under the Division for Science

Independent projects comprise a key, priority funding instrument employed by the Research Council in the effort to enhance the quality of long-term basic research. The Research Council issues one call for proposals per year for funding of independent researcher-initiated projects which is open for all subject fields and disciplines. Grant proposals are assessed by one of seven expert committees, one of which is the FRIOBIO committee for independent projects in biology and biomedicine. Funding for independent projects is allocated in the form of Researcher Projects and Personal Post-doctoral Fellowships, as well as Personal Doctoral Research Fellowships for applicants who are pursuing their doctoral degree at a university abroad. Support for independent projects is primarily provided under the general allocations from the Ministry of Education and Research. The budget includes funding for researcher recruitment in the fisheries, aquaculture and agricultural sectors.

SkatteFUNN

This tax deduction scheme is intended to generate new knowledge, information or experience which is of use in developing new or improved products, services or production methods.

Innovation Norway and the FHF

Both Innovation Norway and the Fishery and Aquaculture Industry Research Fund (FHF) are important external partners for cooperation in many areas.

4.4 Cross-disciplinary initiatives under the Research Council

The Research Council has implemented several large-scale cross-disciplinary initiatives, which may involve activities across the boundaries of several programmes, also the HAVBRUK programme.

Focus on the Northern Areas

In response to increasing focus on the Northern Areas, the Norwegian Government and the Storting (national assembly) have introduced a more cohesive strategy relating to these areas, in which research constitutes a major component. The Research Council will focus special attention on the Northern Areas in 2009. The objectives and priorities set out for each sub-programme under the HAVBRUK programme are relevant in the context of the Northern Areas. Certain ongoing activities under the HAVBRUK programme involve topics of direct relevance to the Focus on the Northern Areas initiative, including production of marine coldwater species, and production under Arctic conditions and under more extreme and exposed conditions. A specific plan has been created for aquaculture research within the framework of the Northern Areas initiative, and is available as an attachment to this action plan. If allocations to research under the initiative are increased, the HAVBRUK programme will boost its level of activity in this area.

5. Budget

Table showing the zero-growth budget for the programme in the period 2006-2010:

Year	2005	2006	2007	2008	2009	2010
Amount in NOK million	76	99	96 ⁵	97.6	97.6	97.6

The budget for 2009 is based on allocations corresponding to those in 2008 from the Ministry of Fisheries and Coastal Affairs (NOK 77.1 million), the Ministry of Agriculture and Food (NOK 1.5 million), and the Norwegian Fund for Research and Innovation (NOK 19 million). Within the financial framework of the zero-growth budget, approximately NOK 35 million is expected to be made available for allocation to new projects in 2009. Cooperation with the Fishery and Aquaculture Industry Research Fund (FHF) may result in additional funding. The budget will be finalised in autumn 2008, and is subject to change.

Areas of focus in the action plan, by sub-programme (target figures)

Sub-programme	Percentage share of research funding
Strategic areas of focus for competitive advantages and wealth creation	20-30 %
Strategic basic research	20-30 %
Sustainability	15-20 %

⁵ The Norwegian Government has allocated NOK 20 million to the Indo-Norwegian research collaboration for 2007. The amount of funding to be distributed to the HAVBRUK programme has not yet been finalised; it has therefore not been included in this table.

Production of salmonids	15-20 %
Production of other species	15-20 %
A knowledge culture and an aquaculture-based innovation system	2-5 %

Growth budget

The Research Council's long-term budget proposal includes a budget increase for the HAVBRUK programme. Special priority is given to the Focus on the Northern Areas initiative in the growth budget proposal. A specific plan has been created for aquaculture research within the framework of the initiative and is available as an attachment to this action plan.

6. International cooperation and internationalisation

International collaboration has become increasingly important to the ability to meet knowledge needs, and opportunities are opening up continually. International research collaboration will be an area of special focus for the Research Council in 2009. A number of areas of aquaculture research are well-suited for international cooperation. Through projects and other activities, the HAVBRUK programme will facilitate the optimal utilisation of international funding instruments. International cooperation must be viewed in the context of the need for greater expertise in areas of national and international interest. International cooperation encompasses international exchange programmes for both fellowship-holders and researchers alike. Planning is underway for research collaboration in a variety of areas. Funding has been set aside for 2009 as part of the effort to enhance international research cooperation. Special priority will be given to collaboration with researchers in the USA, Canada, Russia and China.

North America

The Ministry of Fisheries and Coastal Affairs and the Research Council have together taken the initiative to expand research cooperation between Norway, the USA and Canada in the fields of fish health, genomics, feed and nutrition, and escape prevention. These and other topics are of interest during the programme period.

India

Research cooperation between Norway and India on fish and animal vaccines is now underway as the result of an earmarked allocation from the Norwegian Government. No funding announcements will be issued in this area in 2009.

The EU Seventh Framework Programme

The first call for proposals for research, technological development and demonstration activities under the EU Seventh Framework Programme has now been issued. Norway has provided input during the development of the framework programme, and there are areas which may harmonise with areas of the HAVBRUK programme. It is essential to ensure good coordination between the HAVBRUK programme and relevant activities under the new framework programme, as well as to promote Norwegian participation.

The EU ERA-NET scheme

It will be important to coordinate research activities under the HAVBRUK programme with relevant ERA-NETs.

EUREKA

EUREKA projects that involve Norwegian industry players will be given priority equal to that of national projects.

Others

A number of other countries may be suitable as partners for research cooperation. Plans are being made for expanded cooperation with Japan, for example, where research on seafood safety is a topic of concern. In response to the increasing focus on the Northern Areas, collaboration with Russia on areas relevant to aquaculture may also be of interest.

7. Performance targets, milestones and performance indicators

Achievement of programme objectives must be objectifiable and is to be assessed in terms of performance targets (success criteria) using performance indicators. A number of preliminary performance targets have been set (see below). Further details regarding specification and quantification of target figures and milestones will be provided in the course of the programme period.

Performance targets (success criteria)
High scientific merit <ul style="list-style-type: none">• Generate R&D findings• Generate own technology programmes/large-scale cross-disciplinary projects and initiate cooperation with other technology platforms• Develop professional communities of high international calibre in their fields
Strengthen researcher recruitment <ul style="list-style-type: none">• Development of personnel with top-notch expertise in the programme's scientific thematic areas
Activities between different types of research, disciplines and sectors <ul style="list-style-type: none">• Realise the potential of strengthened interaction between basic research, applied research and innovation• Promote crossdisciplinarity• Develop and employ new techniques and methods• National leadership and coordination of the research within the programme's topics• Achieve satisfactory national distribution of tasks in cooperation with other funding instruments
Promote innovation <ul style="list-style-type: none">• Further develop scientific communities with expertise relevant to private enterprise• Commercialisation of findings• Realise the potential of interaction between basic research and innovation along the entire value chain• Generate synergy and establish cooperation with the other public agencies for innovation instruments• Develop knowledge and innovation that yield growth in the industry's value creation and strengthen its competitiveness and profitability
Contribute to new insights of importance to society

<ul style="list-style-type: none"> • Contribute to knowledge development for policy-making • Contribute to solving problems in society
<p>Strengthen international cooperation</p> <ul style="list-style-type: none"> • Be a bridgehead for expanded collaboration with leading international research groups in their respective fields • Emphasise participation in international research cooperation and establishment of an international network
<p>Emphasise dissemination of findings</p> <ul style="list-style-type: none"> • Active dissemination that also includes a synthesis of programme findings and recommendations on how these can be followed up

8. Organisation

The large-scale programme *Aquaculture – An Industry in Growth (HAVBRUK)* is the Research Council’s most important funding instrument for the aquaculture industry. The programme will emphasise coordinated efforts with the Research Council’s other instruments and programmes with a view to achieving cohesive and effective national efforts in this area. In some cases, for instance research relating to food, markets and framework conditions, the programme will seek to implement joint funding opportunities and joint projects with other programmes. When relevant to the administrative procedures, groups comprising members of the programme boards involved may be formed to assess and prioritise grant applications, but the final decisions will be taken by the programme board(s) that have formal responsibility for project funding. The programme is designed to promote increased national and international cooperation in aquaculture research by using the instruments described earlier in the document.

The implementation of the programme will focus on achieving interactive collaboration between the various players in the innovation system, including universities, university colleges, independent research institutes, private enterprise and the government administration. In order to promote cohesive research and innovation throughout the entire value chain, both Innovation Norway and the Fishery and Aquaculture Industry Research Fund (FHF) will be important as partners under the programme.

The programme is headed by a programme board comprising members from the research community, private enterprise and the government administration. Programme administration is located at the Research Council of Norway and includes personnel associated with Research Council divisions.

9. Foresight

The foresight analysis *Aquaculture 2020*, carried out between autumn 2003 and spring 2004 as a cooperative effort between the Research Council and Innovation Norway, has provided key input to the HAVBRUK work programme. In all, some 70 experts from private enterprise, the research community and the government administration participated in the analysis, which culminated in strategic recommendations for research, the authorities and

trade and industry. Efforts in connection with the *Aquaculture 2020* foresight analysis demonstrated that there is great potential for growth and value creation in Norwegian aquaculture. This is presented in the foresight report *Aquaculture 2020 – Transcending the barriers as long as –*. During formulation of the work programme, the foresight analysis inspired numerous ideas, and many of its insights are reflected in the action plan.

10. Dissemination activities

Communication and dissemination of findings is an ongoing aspect of the programme. The programme board has approved a strategic communication plan for the HAVBRUK programme for the period 2006-2015 which sets high standards for defining and establishing suitable methods of disseminating applicable findings to industry players, the government administration and other users – in addition to scientifically conveyed findings. The programme board will set up practical alliances among users to determine dissemination activities tailored to different needs. Especially important in this context will be to develop innovation systems and arenas for bringing together industry players, government authorities and the specialist communities.

Attachments:

Attachment 1. Programme board

Liv Holmefjord, Deputy Director General of Fisheries, Directorate of Fisheries, Bergen (chair)
Edmund Broback, Board chair/Managing director, Brødrene Karlsen AS, Tromsø
Hilde Toften, Senior Scientist, Fiskeriforskning (Norwegian Institute of Fisheries and Aquaculture Research), Tromsø
Sigurd Stefansson, Professor, University of Bergen
Birgit Dannevig, Senior Scientist, National Veterinary Institute, Oslo
Pål F. Lader, Senior Scientist, SINTEF Fisheries and Aquaculture, Trondheim
Karin Boxaspen, Senior Scientist, Institute of Marine Research, Bergen
Inger Dalsgaard, Adjunct Professor, Danish Institute for Fisheries Research, c/o The Royal Veterinary and Agricultural University, Frederiksberg, Denmark

Deputy board members:

Henrik Stenwig, Director, Health and Quality, The Norwegian Seafood Federation (FHL), Oslo
Grete Skrede, Senior Scientist, The Norwegian Food Research Institute, Ås

Substitutes

Tom Ståle Nortvedt, Researcher, SINTEF Energy Research AS. Substitute for Grete Skrede as of 1 January 2008.

Observers:

Rune Bildeng, Ministry of Fisheries and Coastal Affairs
Kjell Maroni, The Fishery and Aquaculture Industry Research Fund (FHF)
Svein Hallbjørn Steien, Innovation Norway

Attachment 2. Analysis of status and challenges

Research activities under the programme *Aquaculture – An Industry in Growth (HAVBRUK)* are intended to encompass the entire value chain in the aquaculture industry, including the supplier industry. This attachment offers a brief analysis of the status of and challenges facing research and industry with regard to the aquaculture value chain, particularly within the context of the priorities defined in this action plan. For a more detailed analysis of status and challenges, please refer to the HAVBRUK work programme.

3.1 Introduction

To improve the industry's profitability, more attention must be paid to learning about how the markets function. The aquaculture industry needs to be developed within a framework that focuses attention on factors such as food safety and the nutritional requirements of consumers, while being based on sustainable processes that incorporate considerations pertaining to the environment, animal welfare and feed resources. Greater focus on the market by industrial and research circles should come in addition to, not at the expense of, research efforts in biology and technology for optimising production processes.

Aquaculture is an international industry with respect to ownership, markets, customers and suppliers of knowledge, products and services. It follows, then, that aquaculture research must be put into an international context. The development of an industry-based knowledge culture, in which industry players actively participate in and contribute to regional, national and international innovations systems, will be critical. The public authorities will also need to enhance their knowledge to be able to deal with the management aspects of a growing aquaculture industry.

The work programme discusses a variety of research areas. The primary criterion for success of the HAVBRUK programme will lie in the capacity to target activities in research circles and industry alike to meet the need for cross-sectoral projects while at the same time ensuring the implementation of projects of a more basic, problem-solving nature.

3.2 Strategic adaptations and market knowledge

In spite of significant changes in industrial structure leading to better integration of the various stages of the value chain and international ownership, the majority of Norwegian aquaculture production is sold in a commodities market often characterised by stiff competition and price fluctuations. At the same time, the structure of the international seafood market is undergoing change, with an emergence of larger entities that impose greater demands for reliable delivery, quality and logistics.

In future, the markets outside Norway will continue to be the most important to the aquaculture industry – both its seafood producers and supplier industry. The challenge here will be to organise sales in a manner that will allow the extraction of added value, and to gain greater influence by extending control over products farther into the chain toward consumers.

3.3 Healthy food – product quality

The health aspect of food is becoming more and more important both nationally and internationally. With its market-driven production, the aquaculture industry must actively respond to this situation and understand how to exploit the potential of each production species. Accomplishing this will require in-depth knowledge of consumers and the standards they hold for products in the various markets. It will also be necessary to preserve the health-

promoting characteristics throughout production and to disseminate knowledge about the nutritionally significant bioactive components of seafood. Changes in value perceptions, attitudes, habits and behaviour must be measured and incorporated into measures that can be implemented in production to customise fish products for different markets and consumer groups.

Traditional quality relating to appearance, taste, smell and consistency will remain just as important in the future and must be emphasised throughout the entire production process, from the selection of genetic material for farming, to feed, production systems and processing, down to the finished product. The critical areas here are the composition, content and stability of fat in salmonids. With cod, the meat and skin colouring, meat content and consistency, freshness and size are all essential quality criteria. Similar requirements will be established for other production species.

Shelf life is a crucial quality parameter for fish products. While there is not necessarily a connection between food that keeps well and health, there is often a connection between a product that keeps well and its sensory qualities.

3.4 Safe seafood and safe feed

The HAVBRUK programme seeks to meet the need for knowledge about contaminants, particularly environmental contaminants, heavy metals, pesticides and algal toxins, which comprise the primary risk factors within the entire food value chain. Such knowledge is essential because regulations stipulating maximum limits for various contaminants in fish oil, fish feed and seafood are based on factors that are relevant to agricultural production, such as uptake, metabolism and release of such contaminants in various warm-blooded animals – not farmed aquatic organisms. New knowledge of high scientific calibre and extreme accuracy is absolutely critical to changing threshold limits and expanding the framework for value creation. The generation of such knowledge is also given priority due to the relatively recent – and rising – occurrence of certain environmentally hazardous substances, such as brominated flame retardants. Knowledge is lacking about the impacts of such substances along the entire value chain, from the sea to the consumers. There is a clear need for cohesive knowledge development in this area that applies to the HAVBRUK programme as well as the HAVKYST programme and the Food Programme. A comprehensive assessment of the knowledge needs relating to general risk factors for seafood within the perspective of the entire value chain is called for in this context.

3.5 Alternative feed ingredients

A number of reports have concluded that a shortage of the traditional feed ingredients fish meal and fish oil may arise in a few years. Thus it will become increasingly difficult to use fish resources in the production of aquaculture feed ingredients. The lack of suitable fat sources may be the first limiting feed factor, but this may be closely followed by a lack of reasonably-priced protein. A shortage may emerge rapidly, and will pose an obstacle to the growth of Norwegian aquaculture unless alternative feed ingredients are available.

The development and production of tomorrow's feed ingredients will have to be based on both marine and land sources. From the sea, this means better utilisation of marine by-products and the harvesting of lower trophic-level organisms (krill and plankton). Moreover, methods to enable us to exploit these raw materials optimally will be critical. Products from higher plant species are very promising as alternative feed ingredients since they can be cultivated in mass quantities. Vegetable oils appear suited to replacing marine oils, but

progress in this direction must be buoyed by more knowledge about the fatty-acid requirements of fish and the effects of such oils on fish health and disease resistance, as well as about the fatty-acid profile of the food products and their effect on human health. Greater insight into the markets' attitudes to these products is also needed.

Feed ingredients using microorganisms in culture are a current possibility for increasing the availability of raw materials. Bacterial proteins from natural gas are already on the market. Fatty acid-producing microorganisms are among the most important primary producers in the ocean, and can also be cultivated in culture. It will be important to isolate species and develop the technology for efficient production of needed fatty acids.

Several additives, such as pigments, vitamins and amino acids, go into fish feed to supplement the effects of the main ingredients. Efforts to develop knowledge in this aspect of feed improvement fall within the scope of the HAVBRUK programme.

3.6 Nutritional needs and tolerance levels of farmed species

The need for various nutrients differs from species to species and changes during the life cycle of a species. Fulfilling the nutritional requirements of production species is critical to productivity, health and welfare. Furthermore, understanding these requirements is essential to avoiding the pollution and cost associated with overdosing. This nutritional knowledge must be coordinated with detailed information about how fish utilise nutrients in the feed. This pertains to the main nutrients (proteins, fat and carbohydrates) as well as to minerals and vitamins.

There is a need to determine minimum requirements for essential fatty acids in various species, and how a feed's fatty-acid profile affects the biochemical, physiological and other health-related responses in the fish. It is also important to understand minimum amino-acid requirements among production species. Mineral requirements also need to be determined, as do species' tolerances for potentially toxic compounds and various antinutritional factors. Digestibility varies from one feed ingredient to another, and it is very challenging to determine the digestibility of alternative feed ingredients for production species under different environmental conditions. Additionally, effects on feed uptake/appetite, metabolism and subsequent effects on health, welfare and finally food quality also need clarification. Comprehensive knowledge in nutritional physiology of fish, including the use of new methods at the cellular and molecular levels, is necessary for advancing understanding of, among other things, feed effects on an animal's genetic expression.

Today, marine fry are fed living planktonic algae and animals, primarily rotifers and artemia. Despite established Norwegian competence in cultivating live feed for cod fry, dependable production of high-quality live feed remains a challenge. With increased aquaculture production will come the need for a transition to specially formulated feed, so it is vital that the various nutritional requirements of fry be determined.

3.7 Feed and feeding technology

Feed technology here refers to the technological processes at feed facilities that produce complete feeds. Up to this point, R&D in this area has largely been carried out by the individual feed producers. These players possess a considerable knowledge base and Norway is on the cutting edge internationally. The publicly available knowledge base is more incomplete.

Today's extrusion and vacuum-coating techniques allow producers to combine high nutritional values with good physical feed characteristics, but this is expensive due to high energy consumption, low capacity and high equipment investment and maintenance costs. An important challenge lies in generating knowledge that can be used to optimise feed processing in order to reduce costs and raise the nutritional value of feed. This will become even more complex as alternative feed ingredients are adopted.

Feeding technology covers feed storage, technology for transporting feed to cages, feeding solutions with their attendant technology, and equipment for monitoring and controlling feeding. These areas need to be developed alongside feed technology so as to ensure efficient, reliable operation of production facilities.

3.8 Health

The health of Norwegian production species is still plagued by infectious disease, posing an industry-wide challenge. In addition, several non-infectious conditions have recently been identified that lead to birth defects and dysfunctions. There is sometimes a connection between intensive production and these ailments, often called production diseases, which have been in the public spotlight for reasons related to ethics and animal welfare.

Health research has mainly been focused on isolation and characterisation of pathogenic agents and on developing and evaluating diagnostic methods and vaccines. The need for research is still great, as the industry and the government administration will need access to more detailed knowledge about infectious agents, disease progression and spread, pathways of infection and potential treatment in order to determine how best to cope with these diseases, especially when it comes to preventative measures. Effective vaccines against some of the major bacterial diseases in salmonids are available, but it is uncertain whether existing vaccines against the most relevant viral diseases provide enough protection. In recent years, problems with bacterial infections have been growing at production sites for marine species such as cod and halibut, and there are certain loss-inducing bacterial infections for salmon not yet under control. With salmonids, sea lice comprise the largest parasite problem. Today, sea lice infections are treated biologically (with wrasse/cleanerfish), or chemically, which is problematic for environmental reasons. Recent research findings indicate that it may now be possible to develop a vaccine against sea lice. Parasites infect most marine fish, and thus it is important to gain biological and epidemiological knowledge about parasite species and their interaction with host animals.

To be able to prevent and combat disease, it is vital to prioritise basic knowledge concerning the various categories of disease and immune mechanisms. This will provide a scientific foundation upon which studies of individual agents and diseases can build. Efforts should also be made to promote the creation of new techniques and tools to be made available to the various national research institutions dealing with fish health. In Norway, expert epidemiological circles need to be better utilised in order to shed light upon various epidemiological problems, especially in connection with molecular epidemiological studies. The report "Helse- og sykdomsproblemer hos norske oppdrettsarter" (Health and disease problems in Norwegian aquaculture production species, Norwegian only), published in 2004, provides a good overview of the current status and research needs of this area in a five-year perspective.

3.9 Animal welfare

Consumers and public administrators alike are increasing their focus on animal welfare in aquatic production, nationally and internationally. There is a distinct ethical responsibility for animals inherent in Norwegian culture; it is a national objective that food production in Norway be held to a high ethical standard (Report No. 12 (2002-2003) to the Storting on animal husbandry and animal welfare). The welfare of the individual is closely linked to production methods and technology.

Animal welfare is clearly an integrated and multidisciplinary field whose cornerstone is basic knowledge about animal behaviour, physiology and health. The concepts of sustainability and ethically justifiable fish production should pertain to the entire value chain from production to consumer. This can also be beneficial when biological problems are tied in with market-related and socio-economic problems.

Norway is one of the leaders of international research with regard to fish welfare, but there are large gaps in our knowledge in this field. Some of these gaps relate to topics fundamental to the overall concept of welfare, what it means and how it can be measured. The report “Dyrevelferd – forsknings- og kompetansebehov” (Animal welfare – need for research and expertise, Norwegian only) (2005), commissioned by the Research Council as a follow-up to the government report on animal welfare, points to a variety of research tasks for farmed fish. In addition, animal welfare research is needed to establish a scientific basis for the regulatory framework, develop best-practice procedures in the aquaculture industry and develop new technological solutions. It is necessary to develop objective and knowledge-based methods and criteria for evaluating animal welfare, including which environmental factors are detrimental and where to draw the boundaries between good and poor welfare. This last will involve ethical issues requiring consideration of societal and market perspectives.

3.10 Production biology

Emerging trends in the Norwegian aquaculture industry have been toward increasingly intensive systems featuring, among other things, greater control of environmental factors, selected genetic material, intensive fry production, high population densities, reduced water consumption, fast body growth, shorter generation turnover and controlled/season-independent production. An important challenge to Norway’s aquaculture research community will be to obtain expertise to facilitate the development of cost-effective, intensive production concepts that also ensure normal growth and development.

Research in this area has largely revolved around defining optimal conditions for important biological processes of the life cycle, while at the same time to a certain extent searching for a deeper understanding of processes being studied. This has led to some concrete recommendations on how to optimise production, and to some degree defined threshold limit values for key environmental factors. Much of this research has been relatively descriptive in nature; activities have to a lesser extent been able to go into depth and explain the underlying biological mechanisms. Descriptive research can be effective in creating a basis for production, but it yields little basic understanding of the processes examined and in the long run will not establish the foundation needed for future progress and innovation. International evaluations have, in fact, underscored the lack of basic competence in vital biological disciplines as a significant element that may undermine efforts to maintain a viable aquaculture industry. Attention was in particular drawn to Norway’s weak standing in the fields of developmental biology and health in relation to aquaculture research. The rapid developments in biological research show great promise in connection with the development

and use of, for example, molecular-biological methods, and can contribute to an entirely new understanding of basic biological processes. This could be truly significant for activities involving biological problem-solving related to aquaculture, and it would serve the Norwegian aquaculture industry well to gain a leading role in this area internationally.

At the same time, production modes and strategies are undergoing constant modification, and new production species are being introduced. Even though some aspects of basic understanding are species-independent, each new species will bring with it a considerable need for research connected to key biological processes. There are also many examples of production environments stretching the limits of what is sound practice with regard to fish welfare and normal biology. In other words, there is a vast, unfulfilled need for research on basic biology of production species, the interaction between environmental factors and biology, and especially the work of defining a normal range that ensures normal development and justifiable animal welfare and health conditions.

3.11 Production technology

The driving force behind technological progress in the aquaculture industry has primarily been many small companies with limited resources. Nevertheless, the Norwegian aquaculture industry has been a leader in developing new technologies. Norwegian fish farmers and equipment producers, able to rely upon a knowledge base in the technological R&D community, have demonstrated great ability to think creatively. It is important to increase the focus on implementing technological knowledge and solutions in fields such as biology, welfare and health.

Labour-intensive production is expected to give way to more capital and knowledge-intensive production. Such a shift will necessitate research efforts in a variety of fields, such as information systems, automation, remote operation, mechanical operation and support systems, and HES. Today's systems for the growth phase of salmonids at sea are considered relatively efficient. Nonetheless, much still remains to be done to further enhance efficiency, for example by reducing the risk of escape, ensuring optimal water circulation, retarding growth on cage nets, preventing disease, treating for parasites, as well as safeguarding animal welfare and production reliability.

Production technology for continued growth and release at sea must be adapted to the various species' biological requirements. Equipment and processes for the different stages of the production chain need to be developed. As yet there are no production methods or equipment specially adapted to our climatic conditions and species of molluscs, crustaceans and echinoderms. There is excellent potential for refining existing technology and for developing technology adapted to our local species and waters.

3.12 Genetics and selective breeding

The development of systematic breeding of salmonids has been vital to the growth of Norway's aquaculture industry. Advances in breeding have been documented for important characteristics such as growth rate, age at sexual maturation, disease resistance and quality. Norwegian researchers in genetics and selective breeding have gained international renown, and Norwegian know-how in this field is in demand the world over. Breeding work on new production species is contingent on the ability to control the entire life cycle, to clearly define breeding objectives which are pertinent to production results and can be based upon measurable and/or objectifiable data. It also requires access to knowledge concerning technical/biological adaptation to life in culture conditions. For these reasons, breeding work

has only just begun on some species, such as cod and halibut. It is both difficult and costly to raise isolated families for these species, and molecular-genetic methods would therefore enhance the efficiency of the selective breeding programme for salmonids and marine species.

Norway has a well-developed breeding research community, and advances in breeding have contributed greatly to the development of a sizable salmon industry.

3.13 The slaughter process

The aquaculture industry is evolving in the direction of fewer but larger slaughter facilities where the slaughtering process itself is partly automated, from receiving to processing or packaging of the fish. When it comes to slaughtering, fish differ from poultry or mammals. Fish are cold-blooded, and depending on the species, have a certain tolerance for hypoxia and low pH in the brain compared to land animals. As a result, slaughtering is a time-dependent process that is a function of temperature. Today there are several approved methods for commercial stunning/killing of fish, but the industry still faces challenges regarding optimising these methods and raising their capacity.

3.14 Production at exposed (open-sea) sites

The global development trend is toward increased use of exposed production sites, and currently there are several international research groups working on devising technology that allows open-sea farming. This has been incorporated into the NYTEK technical standard, which, for instance, classifies sites as to degree of exposure in NS9415. The future will likely see production operations in open waters. Systematised knowledge regarding failures and mistakes that lead to escapes from the facilities will be invaluable, as will knowledge in characterising risk levels, vulnerability of facilities and ramifications.

In developing open-sea production, it will be natural to seek cooperation with other leading Norwegian technology experts from, for example, the oil and gas sector, where Norway in these past 30 years has earned a prominent position in several marine technology disciplines. Norwegian research institutions, both in the public and private sectors, are world-class.

3.15 Catch-based aquaculture

Globally, catch-based aquaculture makes up a sizable industry, bringing in about 20 per cent of farmed seafood sales revenues for 2003. In Norway, the industry is still small, but interest and activities in it are increasing. The greatest interest is for catching, live storage and continued feeding of cod, pollack, haddock, mackerel, crustaceans and sea urchins. The focus on live storage of aquatic animals is motivated by an increasing market demand for a stable supply and quality of products. In recent years, both the research community and the industry itself have worked at optimising live storage and have developed methods that help to improve survival rate and quality during catch, transport, reception and acclimatisation. There is great potential for further developing this type of aquaculture. Norway is at the forefront in terms of research involving catch-based aquaculture, but many challenges still must be overcome to improve the survival rate, health and welfare of the various species.

3.16 Environmental and ecological effects of aquaculture

A key challenge for Norway's aquaculture industry is to limit escapes from production facilities. In the salmon industry much has been done in the areas of technology development and improvement of routines for operating facilities. While this has resulted in fewer escapes, considerable damage still occurs. Escapes may also be a problem when dealing with the marine species. The potential for ecological and genetic interactions with the surrounding wild fish stocks will become significant, as marine species spend their entire existence in

seawater and can spawn in the production cages. In addition, certain marine species may exhibit behaviour that raises the likelihood of escape.

Another important challenge lies in reducing the risk of spread of infectious disease (bacteria, viruses, fungi and parasites) to wild stocks and between facilities. Enhanced knowledge of the system's sustainability and the environmental needs of the various production species will be crucial to determining where to locate facilities and how to utilise aquaculture areas properly.

The release of contaminants such as delicing agents, algicides and feed that contains antibiotics, fungicides and other additives is another environmental problem. There is relatively good scientific documentation of the breakdown of antibiotics, their retention time in sediment and general spread from the facilities, but in other areas such as the environmental impact of delicing agents, for example, more knowledge is needed.

3.17 Traceability and information flow

In the wake of major food scandals surrounding mad cow disease (BSE), scrapies, hoof-and-mouth disease, and dioxin in chicken feed, the EU has given high priority to food product safety and the introduction of traceability systems. In the period 2001-2005 the EU introduced new legislation on traceability of food products that stipulates requirements for unique identification, ongoing documentation of all suppliers and receivers in the next stage of the food value chain, and documented recall procedures in cases where products are judged to be unsafe.

In addition to the public authorities, consumers and in turn the major supermarket chains pose a variety of specific demands for documentation of what goes into food products, including catch and slaughter methods, feed content, processing methods, and conditions of environmental and animal welfare. This implies a variety of new challenges for the Norwegian food export industry in coming years. In today's globalised trade framework, traceability will be essential; industry players will have to produce objective documentation about their products.

3.18 Logistics, distribution and packaging

On the whole, Norway's aquaculture industry has satisfactory transport logistics, which makes the industry competitive even when distances to markets are great. The transport solutions are flexible and vast resources have been invested in ensuring optimal utilisation of transport vehicles and high-quality handling of goods. With the emergence of the salmon industry, the Norwegian aquaculture industry has refined traditional distribution of fresh fish, and today delivers fresh products around the globe. However, intensified competition and more efficient distribution from other producing nations – as well as market demands and price pressures – necessitate further development of new technological solutions. A burgeoning interest in implementing new solutions for transport by ship and train has been noted. Logistics is largely an operational function in the fisheries and aquaculture industry. In many ways this industry lags behind other industries, where logistics serve to a greater extent as a strategic instrument.

3.19 Marine operations

Aquaculture is based on managing the flow of investment components. Operations dependent on the use of vessels play a key part in this, and may be categorised under the term marine operations. In keeping with the increasing sizes of floating production facilities, production per unit is growing. This coupled with the fact that facilities are being placed in more exposed locations makes for increasingly challenging use of vessels. Examples of marine operations

include net handling, laying of anchoring systems and transporting live fish as well as equipment and personnel.

3.20 Health, Environment and Safety (HES)

Production at more exposed sites adds a new set of challenges to people's capacity to perform required daily operations. Although more and more work is being done with the aid of technology, human presence at the facilities will still be crucial, especially in the role of observer/controller. Knowledge that can improve safety and the work environment is therefore critical to being able to carry out good, cost-effective production.

3.21 A knowledge culture and an aquaculture-based innovation system

The aquaculture industry is rooted in research findings and the experience-based knowledge of the industry players. Continued growth will be dependent on increased interaction between the industry players, the research community and the public authorities. All the parties involved are responsible for ensuring that knowledge acquired through research is used to the benefit of society. The industry must become characterised by an awareness of and established practice for using research toward both continual enhancement and greater innovation, while researchers need to be able to seek inspiration and expertise from industry. This means that the industry must be able to define its research needs. The supplier industry plays a significant role in converting research-based knowledge into practical tools for industry; it is thus a vital participant in the aquaculture cluster and innovation systems. In addition to industry players both in and outside the aquaculture industry, these innovation systems may comprise regional and national authorities, the public agencies for innovation instruments, and knowledge institutions at the regional, national and international levels.

3.22 Knowledge as the basis for the public administration

The authorities lay down key framework considerations for further development of the industry. Public administrators are dependent on updated knowledge in order to integrate perspectives and requirements established nationally and internationally, as well as to be able to set the terms for future standards. Today's production activities are located in coastal areas, and several sites are already in conflict – with business, recreation or preservation activities – regarding coastal area use. More knowledge is needed about the interaction between aquaculture and other interests to enable the authorities to determine a framework that protects the overall interests of society.

Attachment 3. Focus on the Northern Areas in the HAVBRUK programme

Biological and technological adaptations for production in the Northern Areas

Background

The Norwegian Government has launched a national High North Strategy for developing the many opportunities in the Northern Areas. Research constitutes a major component of this strategy, and the Research Council has devised the Focus on the Northern Areas initiative (forskning.nord), which provides a foundation for a broad-based, cohesive research effort in and for the Northern Areas. Under this initiative the Research Council will provide funding for research in *areas that are of particular relevance to the Northern Areas and which have emerged as increasingly relevant in this new strategic context*. Many ongoing activities under the HAVBRUK programme and areas of focus stipulated in the action plan for 2009 involve topics of direct relevance to fish farming in the Northern Areas. If a budget increase is approved, the programme will increase its focus on the Northern Areas initiative.

Analysis of status and challenges

Current production activities in the Northern Areas are, as in the rest of the country, based primarily on Atlantic salmon. Production of salmon-trout, charr and cod are also well established but yield a far lower production volume. Other production species of interest include wolffish, halibut, red king crab, sea urchins and mussels. The potential is relatively great for establishing new industry in the north since there is more available area for production than in the rest of the country. Realising this potential, however, is dependent on a boost in research activity through public funding instruments and industry alike. In addition, the risk of production affecting wild stocks is greater in the Northern Areas, which are home to some of the world's most valuable wild stocks of Atlantic salmon and cod. Since these stocks are of considerable local, national and global interest, an underlying principle of any expansion of aquaculture activities into the Northern Areas must be that interactions are kept to a minimum. Prevention of escapes, spread of disease and genetic influences will be of special concern.

Although several production species are well established in the Northern Areas, there are still challenges in connection with production itself and the conditions under which it must take place. Up to now, the research funded by the HAVBRUK programme has solved many of the more general problems but has only to a small extent focused on the challenges specific to the Northern Areas. For example, the use of age-0 smolt in Atlantic salmon production in Northern Norway has yielded more variable results than in more southerly facilities. It can be reasonably assumed that this variability is to a large extent related to differences in light and temperature conditions in the coastal areas of Northern Norway.

The Research Council's Focus on the Northern Areas initiative also opens up opportunities for further development of Arctic niche products in the aquaculture industry. Innovative research relating to Arctic aquaculture and cooperation with other polar nations such as Russia, Canada and the USA are particularly important within the perspective of the Northern Areas. Northern Norway and Northwestern Russia, for example, have many of the same natural resources and face many of the same challenges for industrial development, such as climate issues, vulnerable natural surroundings and long distances to potential markets.

Research problems relating to the various coldwater species' genetic basis and biological adaptations to a cold climate and special light conditions are essential in the context of the Northern Areas. New knowledge may enable development of production designs and specialised technological solutions tailored to severe northern conditions. At the same time, basic biological research may form a vital basis for assessing the significance of anticipated climate change. According to the UN Intergovernmental Panel on Climate Change, the average global temperature and sea level will rise, the surface area covered by snow in the Northern Hemisphere will shrink, and periods of intense precipitation will occur more often. Storm paths will likely continue to shift toward the poles, causing changes in wind, precipitation and temperature patterns. The impacts with regard to risks and opportunities for the aquaculture industry have not been thoroughly mapped. For example, increased runoff from precipitation may lead to more available freshwater resources for production of salmonids. On the other hand, higher winds and precipitation may lead to more sea salt episodes and changes in water chemistry and additional toxic metals in fish gills. More extreme weather conditions increase the risk of damage and escapes, which will have grave consequences for the Northern Areas due to proximity to important wild fish stocks. Although climate change may bring warmer and longer growing seasons for some species, other species may be adversely affected.

Priorities

The objectives and priorities set out for each sub-programme under the HAVBRUK programme are relevant in the context of the Northern Areas. Certain ongoing activities under the HAVBRUK programme involve topics of direct relevance to the Focus on the Northern Areas initiative. If a proposed budget increase for 2009 is approved, the programme will boost its level of activity under the initiative, in which case the following areas will be given priority:

Priority areas	Sub-programme under the HAVBRUK programme
Acquire knowledge about biological adaptation to Arctic conditions such as temperature and light in production species of interest in the Northern Areas.	All sub-programmes
Develop production designs adapted to Arctic conditions.	Sub-programme 4: Production of salmonids, and Sub-programme 5: Production of other species
Acquire biological knowledge and develop technology for use in Arctic conditions to help to achieve stipulated objectives regarding escapes, spread of infectious disease, genetic influences and ecological interactions, as well as to improve escape prevention and solve problems related to icing and extreme weather conditions.	Sub-programme 2: Strategic basic research, Sub-programme 4: Production of salmonids, and Sub-programme 5: Production of other species
Produce knowledge about effects and impacts of climate change on production activities in the Northern Areas.	Sub-programme 2: Strategic basic research, Sub-programme 3: Sustainability, Sub-programme 4: Production of salmonids, and Sub-programme 5: Production of other species
Develop new Arctic niche products.	Sub-programme 4: Production of salmonids, and Sub-programme 5:

Instruments employed

It will be essential to provide funding for both basic research and research targeted toward solving specific problems. For further details about the various instruments employed under the HAVBRUK programme, please refer to the action plan and the specifications for the individual sub-programmes.