FEUFAR

THE FUTURE OF EUROPEAN FISHERIES AND AQUACULTURE RESEARCH

INTRODUCTION

Project Report, August, 2008 REPORT 1

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The FEUFAR Project

Background

The goal of the project was to define the research required in the medium term (here taken as 10 years), to permit exploitation and farming of aquatic resources set against the context of key challenges and risks for meeting sustainability requirements. The main output of the exercise is a document outlining key challenges, strategic options and the research needs of capture fisheries and aquaculture in European waters and in waters in which European fleets operate under bilateral or multilateral agreements. The project aims to contribute to the development and subsequent implementation of a European Maritime Policy and to further strengthen the European marine research area through anticipation of research needs in the field of fisheries and aquaculture.

Research Methodology

Basically, the methodology consisted of three steps: (i) describe the system, (ii) detect the driving forces in the system and, (iii) by constructing hypotheses about the driving forces, sketch potential scenarios for the future. These different scenarios will provide the basis for the identification of issues, from an economic, ecological, societal and managerial (governance) perspective, which may need attention or be the key challenges in future. Based on the analysis, some of the key future needs for research in capture fisheries and aquaculture were identified.

Contributions

FEUFAR sought the opinions of appropriate stakeholders, and the analysis will consider the possible implications of gradual or catastrophic climate change, new technologies, changes in societal values and organizational structures, globalization of markets for fish and other marine products, food security and health, and changes in management practices or fishing techniques.

Stakeholder participation and dissemination of results were integrated fully in the project. An expert committee consisting of representatives of the research and funding communities assisted in providing feedback into the analysis, and stakeholder groups were invited to formal brainstorming activities during the course of the project. One forum was set up as a stakeholder network of representatives of research, industry and management areas at a regional, European and international scale. A second took the form of an expert workshop, including a broad selection of (representatives of) research and advisory organizations across Europe. The wider audience (including Regional Advisory Council representatives, and hence representing production, processing, societal, and environmental interests) was invited and/or consulted in order to present draft findings and to generate educated feedback.

CONTACT

The project website provides more information about the project, the results of the activities as they became available, and a discussion forum:
www.feufar.eu

Funded by:

Contents

1 Preface

The FEUFAR project was implemented between January 2007 and September 2008. The aim of the project was to develop a research agenda defining the research required in the medium term (10 years), to permit sustainable exploitation and farming of aquatic resources. What we developed was a set of documents outlining the key challenges and opportunities for fisheries and aquaculture and the research needed to meet the challenges or to exploit the opportunities.

Here we present a brief walk-through of the project and the output generated. The final project report consists of a series of sub-reports:

Report 1: The **FEUFAR Project: Introduction** includes

1. Executive Summary
2. The project in a nutshell (extended summary)
3. Introduction
4. Methodology

Report 2: The **Literature review** consists of two parts:

5. Synthesis
6. Overview of foresight studies in fisheries and aquaculture world wide

Report 3: **Systems & Drivers: Trends and Developments** (including hypothesis)
Report 4: **Micro-scenarios**
Report 5**: Macro-scenarios**
Report 6: **Research agenda**, including policy brief and dissemination plan
Report 7: **Annexes**

2 Executive Summary

The goal of the FEUFAR project was to define the research required in the medium term (10 years), to enable exploitation and farming of aquatic resources in the context of key challenges and risks for meeting sustainability requirements. The main output of this exercise is this publication outlining the key challenges, strategic options and research needs concerning fisheries and aquaculture in both European waters and waters in which European fleets are operating under European agreements.

The FEUFAR project applied a foresight analysis using scenarios, building a step by step analysis of the most important factors influencing the future, in this case in fisheries and aquaculture. The process of foresight analysis was embedded and founded on two core pillars; the first cornerstone was the development of research based on the a series of scenarios constructed during the project. These scenarios were built step by step on an analysis of the main determinants of fisheries and aquaculture.

The second cornerstone was the involvement of experts and stakeholders. In all steps of the process, workshops with stakeholders from the fishing and aquaculture industry and their representative organizations, environmental NGOs and consumer organizations were convened. Workshops were organized for experts from the fisheries and aquaculture science community, and joint ones for stakeholders and experts.

This resulted in a research agenda that is logically argued and based on an analysis made by stakeholders and experts beyond the project team. Hence, the priorities described in the research agenda have both a scientific analytical basis and societal reference.

As a starting point of the process the project implemented an analysis of existing foresight analyses in fisheries and aquaculture world wide. This analysis showed both a form of congruence among the studies as well as providing an initial list of topics for future research.

The methodology of the foresight process consisted of six logical steps. In step 1: Define the system: boundaries and horizon, the world of fisheries and aquaculture was split into seven subsystems.

In the next step, for each system part, the key variables and their relationships were determined. These are the so called ‘drivers’ of the system. After these drivers had been determined, each was documented. That means that for each driver we determined the most important indicators and listed how the driver developed over the past 20 years. Also for each driver, a set of different hypotheses, or a number of “possible futures” were elaborated.

Based on the hypotheses for each driver, we constructed hypotheses for the development of each subsystem. These are what are called ‘micro-scenarios’, possible developments for each of the subsystems.

Connecting in a logical way the micro-scenarios of the different subsystems results in the so-called “macro-scenarios”: possible futures for the entire system. The scenarios we developed can be distinguished along four perspectives; scale of management, either regulating issues at a global/international scale or at an international-regional scale or even a national-local scale; the main objective of production, to be centred upon feeding people or mainly on the conservation of the marine ecosystem; the extent to which society is based on environmental awareness and the main fabric of the governance system, be it free market or strict government planning and control.

Five main areas of priority research were identified:

- Fisheries
- Aquaculture

- Ecosystem approach to marine resource management
- Consumer preference and Market development
- Socio-economics and Governance

In addition three cross-cutting themes were developed:

- Data collection and analysis
- Risk management
- Outreach and extension services

Research Priorities for Fisheries

Gear and operational technology
Making gears more efficient and able to mitigate bycatch and discards, limit ecosystem impacts and improve selectivity (with better survival of escaping resources), at the same time improving fuel consumption, are the main challenges to be addressed.

Management and governance
In order to address management challenges, development of multi-annual and multispecies management models and approaches, taking trophic relationships and ecosystem health into consideration, and addressing uncertainty in a clearly understandable manner is needed. Next to this, further development of research into the socio-economics of fishing communities is required.

A market issue in relation to the better use of marine resources taken from the ecosystem and to address the growing demand for marine proteins is the **valorisation of currently underused components of the catch.** This relates both to discards and to waste from processing.

Basic research on populations of lower trophic level resources is needed both for understanding better their place and role in the ecosystem as well as to understand better how fisheries exploitation patterns are changing in respect of other species.

Research Priorities for Aquaculture

Research on new species; diversification of production based on regional characteristics and consumer choice is required. This will include research on species biology (e.g. reproduction, larval stages, fish health and welfare). As for fisheries, research on low trophic level species, including bivalves, is needed.

Research on the development of system technologies. Considering the great competition for the use of coastal areas, the development of offshore technologies and on-land recirculation technologies is required in future. This is all associated with the availability of renewable energy resources. Research on life cycle analysis for the whole system, and a study of risk aspects (insurance, theft) are required.

Improvement of present technologies for inshore aquaculture. Net cages represent some 99% of present production. Recirculated systems have potential, but research is needed to improve fish growth in such systems.

Alternative food for farmed resources. Replacement (as far as possible) of fish meal and fish oil as feed is needed. We also need to develop strains able to grow on diets with lower protein content and lower omega 3 level.

Species enhancement through selective breeding, including hybrids and triploids means that research on GMO is needed to understand whether and how species can be improved by this technique.

Spatial considerations. Considering the great high competition for the use of coastal areas research is needed to define priorities.

Research on the environmental impact of aquaculture activities. Taking into account that this is a main criticism currently, research is needed to evaluate and reduce the negative impacts of aquaculture on the environment and other uses of the coastal zone (nutrient loads, use of energy, escapees, chemicals, diseases, aesthetics).

Aquaculture for other purposes than food production. Production of constituents and molecules for pharmaceuticals and cosmetics means that species (e.g. algae) need to be cultured to eliminate pollution from certain depth zones. We need to culture species to be used as pollution indicators too.

Research Priorities for the Ecosystem Approach

Climate Change focuses on two topics: (1) understanding impacts, (2) adaptation by fisheries and aquaculture sectors. Concerning the likely impacts, we need to address the combined effects of anthropogenic activities and climate change on stocks (distribution, behaviour, growth, food webs), habitats (carrying capacity, hydrodynamics, oxygen depletion, food availability, etc.), as well as knock-on effects for higher predators (birds, mammals). This raises the question of how fisheries and aquaculture will be affected and how they will need to adapt.

MPAs and habitat enhancement. Understanding the effect of MPAs (established for conservation, fisheries and other reasons), their benefits and socio-economic implications (biodiversity, resilience of the ecosystem, 'spillover' effects, trophic cascades, effect of fishing effort displacement) is needed. Methods, tools, monitoring, and siting methodologies need be developed.

In **Coastal Zone Management** there is the need for tools for spatial planning (GIS, VMS). Matching particular activities to the most suitable locations requires appropriate methods for impact analyses of activities and for example for the interaction between fisheries and aquaculture (for space).

Modelling ecosystems. It is **i**mportant to understand ecosystem dynamics, including the implications of aquaculture and fisheries for other ecosystem components. This will require multispecies and ecosystem modelling approaches (to establish indirect predator-prey effects, e.g. on other fish species, seabirds and mammals). Very often models have been developed, but the data to parameterize the models are lacking and the models have not been used operationally for management.

Research Priorities for Consumer preference and Market development

The starting point for market development is the consumer demands for fish and fish products. Important in the food and non-food **Product development from fish and fish products** is research into additional and new products, as well as research in food processing to improve/maintain taste and texture. The development of new types of food for niche markets, but also "From waste to taste" is important: new products from by-products are crucial. In the non-food segment, research should focus on functional and healthy food ingredients and bioprospecting: to develop ingredients from both fish and non-fish marine resources, algae, plants for new and novel uses of compounds, including ingredients for functional food and pharmaceuticals.

Concerning **Consumer health**, focus should be on positive health aspects, such as beneficial health effects of seafood and knowledge of health benefits of farmed fish (new feeding) and shellfish, for example by detecting components beneficial to human health and development of functional food – producing new components with health-beneficial effects. On the other hand, the combined effects of pollutants should be subjected to study, along with the further development of quality control technologies (freshness, pathogens or contaminants contents, for breeding) that are cheap and quick (automation).

Traceability is important for several purposes, to assure consumers, to document sustainable harvesting, to document origin, to document all sources of input, and days since catch. On the technical side, the further development of standards, procedures and systems is needed. The focus on traceability is moving towards the business side, seeking new applications to ensure competitiveness of European producers.

Concerning **Certification and branding (labelling)**, a main concern is to address the issue of the need for information: what do consumers need and want of information? This leads to the research needed for effective labelling systems, including health, fish welfare, origin, treatment and the scientific development of labelling and certification standards.

Research Priorities for Socio-economics and Governance

Socio-economic analysis & impact assessment. There is a clear need for implementing general socio-economic studies, provided a sound database is established and available, and for impact assessments to be executed. This entails standard and continuous research into the economics of activities of harvesting marine resources (i.e. fishing, aquaculture, recreational fisheries) to maximize efficiency and production as well as into more specific issues, such as:

- Socio-economic structure and the effects of activities within sustainable ecosystem management
- Socio-economics of coastal zones and the coastal communities (alternative uses of the coasts and resources and alternative employment)
- The development of socio-economic tools to gather views of stakeholders (e.g. 'mind-mapping' techniques) and to promote understanding among different 'users'.

Addressing **governance** issues has already become a standard feature in marine research, dealing with cases of multiple stakes and stakeholders and the integration of domains in integrated management tool development such as the ecosystem approach to marine management. A major area of further research in this light is bringing together further the triangle of stakeholders, management and scientific support to policy. Development of innovative, adaptive, context-specific (regional) management tools and systems based on inclusion of stakeholders and geared at the creation and acceptance of shared knowledge is called for.

The above is related to the more general development of **new management tools** and the further application of newly developed management instruments. This includes the further development and implementation of integrated coastal zone management, including optimization of the use of instruments such as MPAs, optimal spatial location of activities and conflict-resolution techniques and the search for more efficient and (cost-) effective methods of management and enforcement through enlarged legitimacy and compliance through, for example, co-management arrangements, co-creation in policy development and multi-stakeholder evaluation of impact assessment.

Research Priority cross-cutting themes

Data collection and analysis

Currently, data on the socio-economic aspects of fisheries, aquaculture, recreational fisheries (costs, earnings, investments) and ecosystem goods and services are generally not available. Next to the sheer collection of the data, there is a research issue on building a 'knowledge base' (applied and fundamental research) to improve understanding of how systems (from individual animals, through populations and ecosystems and from individual economic agents through to socio-economic communities) work.

Risk management
Risks and uncertainties occur throughout the production cycle and ecosystem on different scales and impacts, from the impact of climate change, invasive species, pathogens, Harmful Algae Blooms through to uncertainties in stock assessments and policy impact. Risk analysis needs to be a basic component of impact assessments of policies as well as the basis for their development.

Outreach
Under a number of research issues, the need for demonstration and promotion has been identified. Areas that can easily be identified lie in the field of the health effects of fish consumption, the promotion of seafood, and the communication of the results of scientific research to the wider public in a manner and format appropriate for the target group.

Output

The main output of the project has been a discussion between the experts in the project team, experts and stakeholders on developing research priorities in the fields of fisheries and aquaculture. This process has been documented and continuously disseminated through the project website. In the process, a number of project documents and workshop reports were drafted. In addition, members of the project team frequently gave presentations on the scope, process and results of the project to an even wider audience.

With the production of the final report a start can be made to discuss further the priorities that were developed. In order to facilitate this discussion, a user-friendly leaflet presenting an overview of the project and its process and methodology and the final outcome (a research agenda) will be prepared and distributed widely to both the research and stakeholder community. In addition, the draft final report will be sent to experts and stakeholders for comments. These comments will be listed as an addendum to the final report.

The results of the project are the starting point for a discussion on the political priorities and the funding of relevant research. Some topics mentioned above are already part of current national and international research programmes. However, what becomes clear in the analysis is that although attention is already given to fisheries and aquaculture, the total effort in these fields of research should be increasing rather than declining. In addition, especially in the fields of management and governance, the scenarios demonstrate a pressing need for the development of integrated multi-disciplinary, multi-stakeholder tools in order to address (spatial) planning and prioritization issues. Where tools are developed already, they are in urgent need of being operationalised better.

Also pivotal in the entire research effort has been an understanding of the position of the consumer and their preferences next to incorporating an understanding of a societal view on the sustainable utilization of marine resources. Utilization and conservation of marine resources in a sustainable manner requires a sustainable management system, balancing ecological, environmental and societal aspects. None of the research priorities presented above can be taken up in isolation, but should be considered integrated with the other aspects.

3 The project in a nutshell

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4 Introduction

The overall goal of the FEUFAR project was to define the research required in the medium term (10 years), to permit exploitation and farming of aquatic resources (finfish and shellfish) in the context of key challenges and risks for meeting sustainability requirements. The project contributes to the implementation of European Maritime Policy and the further strengthening of the European Marine Research Area through better anticipation of research needs in the fields of fisheries and aquaculture.

Earlier 'horizon-scanning' initiatives provided imagined 'futures' for capture fisheries and aquaculture around the world, but there was relatively little attention paid to the implications for future fisheries and aquaculture research specifically. The principle task of FEUFAR was to launch a Foresight exercise and thereby to identify research requirements in the area of fisheries and aquaculture, to define the key challenges and risks, and to develop possible scenarios for addressing sustainability targets. The project allows better anticipation of future research needs and funding priorities and identifies knowledge gaps.

4.1 Objectives

The objectives of the project centred on specific and clear goals:

1. To provide a 'state of the art' inventory of existing foresight analyses (fisheries and aquaculture, and related marine science and technology) world wide, including the distillation of key messages, and identifying themes, threats and drivers and developments in science and policy.
2. Based on the 'state of the art' and through input from stakeholders from the fishing and aquaculture industry and their representative organizations, environmental NGOs and consumer organizations and from experts from the fisheries and aquaculture science community, to build scenarios (possible futures) based on identified key variables and trends, taking into account interactions between ecological, economic and societal factors.
3. Based on the 'state of the art' and scenarios, to define key challenges, strategic options, and paths towards a more sustainable future, and to identify appropriate research needs.
4. By organizing a platform for discussion and priority setting, to generate input from all relevant parties (fisheries and aquaculture sector, marine science and technology, research institutes, policy-makers) to the process, substantiating the analysis and at the same time generating support for the outcome. The project brought together relevant and key players through a series of workshops to provide input to the process and to discuss findings. Further, effort was put in to disseminating both the outcomes and the steps of the process through such means as publications, leaflets and a website.

4.2 Perspective

Recent predictions suggest that world fish consumption will continue to rise to some 17.1 kg per capita per annum by 2020, having been less than 7 kg per capita in 1950 (Delgado *et al.*, 2003). In contrast, there is evidence that global capture-fishery landings have declined since the late 1980s, by an estimated of 0.36 million tonnes per year (Watson and Pauly, 2001). The proportion of total fish production obtained through aquaculture is predicted to increase markedly over the next two decades, (reaching 41% by 2020), but capture fisheries are predicted to grow by <0.7% per year, because many stocks have already been overexploited.

In 2003 the EU-25 production of fishery products (capture fisheries and aquaculture production) was 5% of the world's total. Four of the EU-25 Member States (Denmark, France, Spain and the UK) accounted for 56% of total EU production in 2003. The production in 2003 (7.3 million tones) was about 11% less than the estimated total production in 1990 (Eurostat, 2005). EU-25 aquaculture production was just 2.5% of world production in 2003 (89% of the total production was by Asian countries).

However, the EU-25 production increased by about 35% from 1990 to 2003 (to 1.4 million tonnes). In the same period, Norway's production (largely of Atlantic salmon) increased by 287%. Four Member States (France, Italy, Spain and the UK) accounted for 68% of EU-25 production in 2003.

In 2003, EU-25 capture fisheries accounted for 6.6% of the world's total (~5.9 million tonnes). The 10 new Member States only accounted for 9.1% of EU-25 catches in 2003. Between 1990 and 2003 the EU-25 catch decreased by an estimated 18%. Over the same period the combined catch of Iceland and Norway increased by 46% and world production by 5%.

The value of landings in Spain is nearly twice as high as the landings of any of the other EU-25 countries. Norway's landings have a value higher than that of all EU-15 countries except Spain. The EU-25 Member States have an overall negative balance in trade in fishery products, both in terms of volume (-3.4 million tonnes) and value (-€ 9,600 million), and this negative balance has increased in since 1990. Only five EU-25 Member States (Denmark, Estonia, Ireland, Latvia and the Netherlands) have positive balances in terms of value. France, Germany, Italy, Spain and the UK are the biggest net importers among EU Member States.

Of the EU-25 Member States, Greece has the largest number of fishing vessels. However, on average these vessels are small (median power 5 kW) compared with the vessels from most other countries (e.g. Spain with a median power of 82 kW). Since 1990, the EU-25 fishing fleet has decreased by 10% in number (to 92 422 in 2004), by 7% in total tonnage (to 2.1 million tons) and 9% in total power (to 7.5 kW). Since 1990 there has been a general reduction in the number of fishers in most European countries to around 256 000 in 2003 (33% in Spain, 19% Italy, 8% Portugal, 7% France). A recent EU-funded study (Lot 23: Coordination and Consolidation Study) identified 343 'zones of dependence' having a measurable degree of dependence on fishing. Of these, nearly 40% fall within 'Objective 1 regions', where development is considered to be lagging behind the rest of the Community. 63% of European fishers are employed in the Objective 1 regions. The European fish-catching sector is composed of many different sub-fleets. Fleet segments differ from one another in terms of their vessel numbers, physical capacity and value to the European economy.

The EC's Aquaculture Strategy under the Common Fisheries Policy (CFP) reform sets an ambitious target, to increase production and employment in aquaculture, creating up to 10 000 new jobs in the sector by 2008 – an increase of more than 15%. Some experts believe that by 2020 Norway will be producing as much as 400 000 tonnes of cultured cod, halibut and turbot each year; this would be twice a much as Norway's cod quota from the wild. Although there are opportunities for further growth in the aquaculture sector, there are also new concerns associated with the release of pollutants and the requirement for wild-caught feed-fish. According to one estimate, aquaculture will consume the entire world production of industry-derived fish oil by 2006.

In September 2002, during the Johannesburg World Summit on Sustainable Development (WSSD), governments agreed to a restoration of stocks to levels that can produce the maximum sustainable yield by 2015. The EU 6th Environmental Action Programme, the FAO Reykjavik Declaration on 'Responsible Fisheries in the Marine Environment' and the OSPAR Bergen Declaration have also committed countries to halting current patterns of biodiversity decline by 2010 and encouraging an 'ecosystem approach' towards the sustainable development of the oceans generally.

There are several European initiatives which aim to protect and restore the functioning of natural ecosystems. The EC's Biodiversity Strategy states that the Community should 'seek the conservation and, where relevant, restoration of ecosystems and populations of species in their natural surroundings'. Article 2 of the EC Habitats Directive (1992) requires measures to be taken to maintain or restore natural habitats and species of wild fauna and flora to a favourable conservation status. The EC Water Framework Directive (2000) requires measures to be taken to protect and enhance the status of aquatic ecosystems, including estuarine and coastal waters. Article 2 of the OSPAR Convention requires Contracting Parties to 'protect the maritime area against the adverse effects of human activities so as to safeguard human health and to conserve marine ecosystems and when practicable, restore marine areas which have been adversely affected'.

There are many other important regulations, instruments and agreements relevant to fisheries management. Notable among these are the UN agreement on the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks (United Nations, 1995), the International Plan of Action for the Management of Fishing Capacity (FAO, 1999), International Plan of Action to Prevent, Deter and Eliminate Illegal, Unreported and Unregulated Fishing (FAO, 2001), the Agreement on the Conservation of Small Cetaceans of the Baltic and North Seas (ASCOBANS) and the UN Fish stocks Agreement (UNFA).

Fishery management relies heavily on scientific evidence; research makes a significant contribution to the translation of the CFP, and other policy drivers, into practical effect. Fisheries research is funded for the principal purpose of providing scientific evidence and advice to fisheries managers. The total combined annual fisheries research budget of Europe amounts to some €160 million and represents a very significant body of scientific knowledge (MARIFISH, 2005).

Recent revisions to the CFP, as set out in the new basic regulations adopted in December 2002 (Council Regulation 2371/2002), imply a substantial challenge for fisheries research. Research and science will have a crucial role in the development of necessary tools for the operational and practical implementation of fisheries management, and to fulfil the overall objective of the CFP to secure sustainable fisheries within an ecosystem approach.

Challenges include a need for broader and more ecosystem-based fisheries advice; high precision in short-term forecasting and Total Allowable Catch (TAC) advice; scientific input into the development of longer term management plans; and finally closer links with socio-economic research. In order to meet these challenges, the research needs to be well coordinated and as efficient as possible, especially in light of the constrained levels of funding available for fisheries research.

The need to adopt an ecosystem-based approach for fisheries management is a priority, as indicated by the now developing European Marine Strategy, which aims to give additional protection to the European marine environment. There are significant challenges here for fisheries science – understanding the impact of fishing on the marine environment, assisting in the development of alternative management measures, and how to monitor recovery, through the development of appropriate indicators. To meet these challenges, the Marine Strategy calls specifically for coordinated programmes of science, of the nature proposed under FEUFAR.

4.2.1 Institutional context

In September 2002, during the Johannesburg World Summit on Sustainable Development, a resolution was approved addressing three major issues (eliminate illegal, unreported and unregulated fishing; application of the ecosystem approach; facilitate the use of marine protected areas) to result in 2015 in a restoration of stocks to levels that can produce the maximum sustainable yield with the aim of achieving these goals for depleted stocks.

The Common Fisheries Policy of the EU in its latest reform (2003) and the proposal for a Marine Environment Strategy (2005) incorporated these concerns to comply with global policy objectives, which would probably be intensified after the implementation of the Maritime Policy under the Green Paper in preparation by the EC.

4.2.2 Environmental context

Both fisheries and aquaculture rely upon renewable and natural resources and are in this respect competing with other users of marine resources and space. In the recent proposal by the EC for a Marine Environment Strategy, fisheries are considered to be one of the main threats to the marine environment. The main strategic component from a biological and environmental perspective is to comply with the impact of climate (including long-term evolution) and environmental drivers on living resources, and the ecosystem response to fishing.

Competition with other users of the environment, such as oil and gas extraction and commercial shipping, do have an impact on living resources and may reduce the habitat available for fishing and aquaculture. Effects such as noise and potential harmful substances from these activities can interfere with fish recruitment. Similarly eutrophication from agricultural production on land and pollution from urban areas can have an effect on the marine ecosystem, and consequently on the fisheries and aquaculture sectors.

Fisheries and aquaculture food systems management are changing, driven by complex environmental, technological and policy factors. Environmental regulations have altered the conditions for the fishing and aquaculture industries, and growing public awareness will generate more consumer pressure in many areas, including food safety and animal welfare.

4.2.3 Sectoral context

To obtain more food from the oceans, better use of natural resources is required, and this must include allowing overfished stocks to recover, avoiding wastage, making renewed efforts at better management of fisheries, and aquaculture growth. After a century of geographical expansion followed by technical intensification, the effective management of fisheries needs to enter a new era. In this respect, aquaculture activities follow the same trends and are already facing the same challenges, e.g. the focus on sustainability, environmental impact and food safety in a global market.

This implies for fisheries and aquaculture the challenge to develop capacity for supporting research and management, allocating specific exploitation rights (particularly in the context of coastal zone management for aquaculture and small scale fisheries), improving monitoring control and surveillance, and improving reporting on inputs and outputs.

4.2.4 Socio-economic context

Fisheries and aquaculture are concerned with challenges on both macro- and micro-economic levels, including investments in vessels and other facilities, their profitability, linked to both to internal (e.g. fish stock status) and external (e.g. oil price) factors, limited flexibility, and, on a micro-economic scale, the responses of fishers to management measures such as closed areas. In recent years, the social aspects of policy implementation necessitated further integration of analysis, along with the encompassing of biological and economic assessments to consider social and societal aspects. Hence, the governance of fisheries and aquaculture management to focus on integration of ecological, economic and societal aspects, with specific attention paid to:

- the acceptance of new governance and management rules;
- increased involvement of stakeholders in the management process.

The link between development of the natural system (generally degradation), economic/social impact and pursuing political pressure is a key governance issue to address in order to obtain ecological, economic and societal sustainability, particularly in the coastal areas. Progress still needs to be made in order to understand and predict the response of natural systems and human behaviour to management decisions, i.e. the knowledge-based approach.

The challenges that lie within European fisheries and aquaculture production systems are no longer just manifest through the provision of safe and healthy food. They are also strongly influenced by an increasing number of environmental and societal goals. A broad interdisciplinary approach, indicating a wider scope of implications throughout society, is therefore essential if we are to understand fully what can be achieved, and how.

4.2.5 Research context

There is a need for substantial scientific effort to develop and manage aquaculture and fisheries activities within the framework of sustainable exploitation. In order to address this, research domains have to cut across science themes, including modelling, socio-economics, basic and molecular biology, sustained monitoring and the provision of scientific advice. One of the major challenges marine research institutions are facing is the provision of insight into ongoing developments and the state of the ecosystem, and to provide a basis for innovative solutions. This is of particular relevance when stakeholder confidence in existing assessment and management models ebbs away. There is a need to focus on methods and models, including fleet interactions, geographic differences, and the impacts of the environment on fish stocks and of fisheries on the ecosystem.

New approaches and models are also required to communicate complex insights effectively to the increasing number of stakeholders involved in the decision-making process (e.g. by the development of efficient partnerships between public research and research by the industry). This addresses in particular:

- social and economic sciences entering a new paradigm wherein they have to deal together with the same object, rather than looking at it separately;
- ecosystem-based management, which considers all parameters impacting on a system, including human activities affecting the ecosystem in a particular geographic area.

Through broader understanding of the different driving forces within food systems, this project has aimed to deliver a research agenda that can provide additional clarity in these complex matters. The ultimate aim was to create a self-evolving scientific agenda that can be progressively better equipped to take on major future challenges through research; training and education, on the improvement of aquaculture systems, in trying to make them productive, yet environmentally clean and sustainable. This FEUFAR report aims to provide policy-makers with tools to establish a more equitable balance of food security within European society.

4.3 Relevance of the study for Policy Development

This report provides a prospective research agenda for fisheries and aquaculture, contributing to the implementation of a future Maritime Policy and to further strengthen the European Marine Research Area through a better anticipation of research needs, taking scientific, policy and sectoral contexts into consideration. In particular in the **fisheries** primary sector:

Balancing the capacity of fisheries with natural stock renewal

Declining yields, shrinking stock biomass and uncertain profitability are characteristics to incorporate in any commercial fisheries analysis. In those that are unmanaged or managed as *de facto* open-access fisheries, the race for fish tends to create a fishing capacity that is greater than needed to produce a sustainable yield in a viable manner. Overcapacity and capacity management have become key issues in fisheries management. Overcapacity and overfishing are symptoms of the same underlying management problem – the absence of well-defined property (or user) rights. Although this situation might change in future, the improvement of monitoring, control and surveillance (MCS) and fisheries data collection and reporting will remain of importance.

Evolution in management and governance

Fishery management is based largely on annual fish stock assessments. Multi-annual assessments incorporating both biological and socio-economic considerations can provide a medium- to long-term planning horizon to the decision-making process. Within the context of marine fisheries management, this includes:

- the more explicit recognition of access rights in both artisanal/small-scale and industrial fisheries, in order to reinforce management input and output controls;
- the management of fleet capacity and the clarification of the role of industry subsidies that may distort production arrangements;
- the strengthening of MCS as a means of ensuring effective implementation of agreed management measures.

Additionally, stakeholders' input is being used increasingly in the management cycle. In the development of European fisheries management, new analytical tools (including fleet interactions, impact on the environment by fisheries, and vice versa) will allow communication of complex insights effectively to the increasing number of stakeholders involved in the decision-making process. Article 10 of the UN Fish Stocks Agreement includes the obligation for states to "agree on decision-making procedures which facilitate the adoption of conservation and management measures in a timely and effective manner". In this context, decision-making procedures will involve a variety of inputs such as research and development with broad participation by stakeholders in specialized instruments (i.e. Regional Advisory Councils).

Curbing environmental degradation and innovative use of biological resources

EU fish stocks have been declining for many years, and the reduction of fishing effort has been the main measure used to try to recover overfished stocks. However, because of the cost and difficulty of reducing fishing capacity to a level compatible with stock recovery, these actions have often been ineffective, insufficient and slow, while catching efficiency and the real fishing effort in a sector increases. To this end, technical measures and such instruments as seasonal closures, mutual moratoria, Total Allowable Catch (TAC) and quotas have been the main tools for fisheries management and stock rebuilding, but the effects vary based on the stocks and geographic areas in question. It is obvious that recovery plans will have significant costs both in the form of recovery expenses and socio-economic repercussions to the stakeholders involved.

The reformed CFP now provides for the progressive implementation of an ecosystem approach to fisheries, encompassing anthropogenic impacts other than fisheries. Two examples illustrate this component:

- in estuaries, impairment of water quality and dredging have modified extensively the quality of nurseries and the recruitment capacity of the habitat; in the same context, anadromous species are under threat.
- global warming should impact on fish behaviour and migration patterns, displacing nursery grounds, and change food web features.

The major concern European **aquaculture** has to face lies embedded in the concept of sustainable development. In practice, this focuses on better use of natural resources (including fishing for fish meal) and better protection of consumer health, while preserving the competitiveness of the sector in a global and open economy.

Species composition

The focus on only a limited number of species at an industrial farming scale (oysters, mussels, salmonids, sea bass and sea bream) when the market demand is for more diversification is a threat to aquaculture development and market share when competing with fisheries produce. The horizon for developing production of a new species is decreasing, now being in the range 5–10 years.

Environment

Environmental constraints, such as those resulting from global pressure on coastal zones, and the shortage of available biological resources (e.g. fish oil), call for improvements in technology (e.g. extensive polyculture systems, offshore facilities and recirculation technology) and enhanced use of production input/factors (e.g. fry, food, vaccines). This development in turn can affect both the perception by consumers of the sector as much as it can develop the scope for growth of the industry.

Requirements for quality control and traceability (including imports), the risks of epizooty (including those from the trade of live animals), and environmental constraints on genetic issues deriving from selective breeding programmes, are increasing everywhere. The issue of fish-meal-based feed for carnivorous species may slow down the development of this industry.

Demand

The increasing demand, both globally and on the European market, for high quality and/or labelled products is still based on a perceived image of aquaculture and seafood produce as being natural and healthy. Simultaneously, increasing competition in the market, particularly from imports from low-revenue countries, leads to a greater concern about the costs of production (e.g. the cost of fossil energy, the impact of mechanization) and macro-economic indicators (life cycle of products, employment).

Shellfish specificities

Shellfish farming, relying directly on natural resources, is subject to various risks (toxic algae, microbiology, pollutants), so has a direct bearing on the expectations of society in terms of safety and food quality. Traditional activities should accommodate European standards, which lead to increased domestication (hatcheries, purification basins, genetic selection, etc) and higher requirements in terms of the microbiological quality of inshore waters.

Aquaculture interaction with industry and consumer

All these actions need to be built on a total value chain approach, including aspects of live fish traits and the impact this will have on harvesting operations, processing and the quality of the final product for the consumer. Today's consumers and the public generally call for better and clearer information to sustain their consumption.

In the **seafood processing** industry, the main considerations centre on consumers' trust in safety and quality of the seafood offered on the market. In order to maintain this, new concepts of transparency are required. Innovative consumer-driven seafood production is necessary to satisfy the needs and expectations of European consumers. Some consumers are critical with regard to the environmental and animal welfare aspects of seafood production. The license to produce requires more and assured environmental and welfare care in sustainable fisheries management and aquaculture.

Health promoter

In the near future, seafood's contribution to reducing the incidence of chronic disease will be of utmost importance. The production of functional seafood with high levels of Ω-fatty acids, fish proteins and other health-promoting nutrients is challenging for both fisheries and aquaculture. It has become clear that seafood consumption assists in the prevention of chronic nutrition-related diseases and of certain forms of cancer. Understanding the impact of nutrients from seafood (amino acids, peptides and trace elements) on the health of (target groups of) consumers will have a huge impact on the consumption profile of European consumers and therefore on the industry.

Consumer protection (toxicity, disease)

Food safety concerns require particular attention to be paid to pathogenic infectious diseases, bio-toxins and toxic contamination. The level of the regulatory intensity will impact both on production costs and on the costs of compliance, as much as it will hinge on consumer acceptance.

New products

Product development based upon consumer perceptions, expectations and preferential behaviour need to be developed and therefore must be consumer-driven. Special attention should focus on two categories of seafood consumers: younger people and the effects on their long-term health, and immediate health effects on elderly people.

Development of marketing processes

Both "slow" and "fast" food movements can be provided with tailored healthy seafood, and can lead to a higher price for value. These concepts will lead to more diversification and economic profit in seafood production and marketing. Any improvement in the European policy to improve the European seafood production will have an impact on the import of seafood from other parts in the world.

4.4 Implementation

Fisheries, aquaculture and their management are by their very nature an international issue, because fish stocks are a common resource (be they capture fisheries, the environment in which aquaculture is taking place, or a resource for aquaculture production) that exists across national boundaries. In addition, the fabric of fisheries and aquaculture policy is such that national policies are determined mainly by the EU Common Fisheries Policy and such fora as the International Council for the Exploration of the Sea (ICES) and Regional Advisory Councils (RACs) such as those for the North Sea, Pelagic, Baltic and Mediterranean. Hence, this foresight was exercised at a European/international, rather than national level.

Noting the above, the consortium chose to incorporate stakeholder participation and dissemination of the results throughout the entire cycle of the project by embedding the consortium in two wider fora. An expert workshop, consisting of a broad selection of (representatives of) research institutes across Europe and from scientific networks such as the ESF Marine Board, EFARO and EAFE has been used to provide peer input to the process. In addition a stakeholder network, consisting of representatives of industry (throughout the production and processing chain), (environmental) NGOs and consumer organizations have been involved.

In order to obtain an even more broadly critical review of the findings, the draft final report has been forwarded for comment to a range of organizations (*inter alia* RACs, EAS, FEAP, EAFRO, EAFE, ESF-Marine Board, ACFA, CNPMSM, EBCD, European Anglers Alliance, European Consumers Organization (BEUC), FEFAC, Greenpeace International, Hellenic Society for the Study and Protection of the Monk Seal, Invest in Fish South West, IUCN, MED AQUA, MED RAC, Medisamak, NFFO, Nireus Aquaculture, North Sea Women's Network, Office for preservation, diversification and development of Slovene Marine Fisheries, PEPMA, ICES, PFA , NVZ, TEST ACHATS and UNICOOPESCA. Reactions are presented in Annex 1.

Also, the project built on the results and progress of other EU and nationally funded projects such as DEGREE (on the reduction of the impact of fishing gear on the environment), CAFÉ (on effort management in fisheries), CEVIS (on evaluation of fisheries management systems), PROTECT (on the subject matter of closed areas) and UNCOVER (on the subject of recovery plans). In the realm of aquaculture, the project built on the results and progress of Priority 5 and 8 EU-funded projects such as IMPACTFISH (Impact Assessment of the FP4 and FP5 Research Programmes on Fisheries, Aquaculture and Seafood Processing Research Area and the Fishery Industry), the CONSENSUS initiative (a multi-stakeholder platform for building a protocol for sustainable aquaculture development), PROFET (identifying aquaculture industry needs in RTD), and PROFET POLICY (aimed at bringing RTD in fisheries and aquaculture to policy-makers). In terms of innovative consumer-driven seafood production, health attributes and development of new products, FEUFAR built on the results and progress of the SEAFOODplus integrated project (aimed at reducing health problems and increasing well-being among European consumers) by applying the benefits obtained through consumption of health-promoting and safe seafood products of high quality.

4.5 Foresight analysis

Aiming at scoping the future of fisheries and aquaculture in Europe and hence defining the research required to permit the exploitation and farming of aquatic resources in the context of key challenges and risks for meeting sustainability requirements, the foresight exercise focused on future challenges for the exploitation and farming of aquatic resources, specifically on possible scenarios for meeting sustainability requirements (from international conventions) and results in the identification of areas in which additional research is required.

Following FAO (Bruinsma, 2003) the basis of any scenario exercise is of course a description of the current state of affairs and projections. These analyses and predictions have to take account of geographic, sectoral and sustainability aspects. In this it has to be taken into account that next to deciding on which variables to include in the analysis (for example demand, production and ecological variables) comparable datasets have to be available over the entirety of the several subareas included in the study. Effort has to be devoted to creating a consistent set of historical and base-year data on the basis of which the scenarios can be developed.

Next, the future has to be projected. In part this can be done by so-called “trend extrapolations”. On the one hand this requires proper description of trends at all the scales of analysis involved, on the other hand it calls for the availability of necessary data, be it qualitative or quantitative. In addition, and this is crucial to the exercise, a common understanding of the desired future state has to be elaborated. Following Goleman (2002), the scenario on the one hand calls for anticipation of the future, on the other, the drafting of a scenario is a process in which patterns and mechanisms are unfolded and projected into a future state.

Scenarios are imagined ‘futures’. They do not come singly, as a forecast would, but in sets of alternatives. Scenarios are not necessarily "visions" or "plans", but they can help to guide strategy. They describe both optimistic and problematic futures. Each may concentrate on a different driver of change (e.g. sustainable development) or a different area of influence (e.g. fisheries or aquaculture development).

Good scenarios help us to understand how key drivers might interact and affect the future. Scenarios create representations of alternative worlds and can offer an inclusive and systematic way of thinking about how the future might look. Scenarios go beyond a single best estimate, or a ‘high’ and ‘low’ projection both side of this, and encourage us to explore a number of different, logically consistent pathways.

Scenarios describe the relevant world as it might be, far enough ahead to be beyond the scope of trend extrapolation, and after radical shifts in the social and cultural conditions which we unconsciously assume to be fixed. The wealth of recent experience suggests that there is no single strategically best way to work with scenarios. However, well-designed scenarios do seem to share some common features:

- **DIY** *(do it yourself)***:** scenarios are best created by a panel, or at least commissioned then explored and focused by a panel.

- **10 years distant, or longer:** scenarios are for a future we cannot see, yet for which we must still plan. Their horizon is typically around ten years, although it may be as little as five years, when change is fast or chaotic, and as long as 50 years when strong and unambiguous drivers are operating.
- **Credible:** scenarios are not forecasts. They can usefully examine fairly extreme sets of consequences of the driving forces. However, it is important that those involved feel comfortable with each scenario; however surprising it is, they should be able to imagine living in such a world.
- **Internally consistent:** it follows that the social, political, economic, environmental, technical and cultural features of a scenario should hang together, as they would if a piece of consistent history had been written leading up to that state of affairs.
- **Focused:** the best scenarios dramatize a few key features or events of prime concern.
- **Plural:** some groups have experimented with a unique scenario. This is usually a mistake, because a single view of the future is too easy to confuse with a forecast. The practitioners' consensus is that two is a minimum and, in the time usually available, four is a maximum.
- **Striking and sometimes uncomfortable:** one of the prime objectives of scenario work is to startle managers, to fire their interest, and to get them thoroughly involved and excited. Scenarios should never be boring.
- **Dramatized:** scenarios work best when they are dramatized in various ways, brought to life by scene-setting, stories, case-studies metaphors or encapsulated in memorable and vivid catch-phrases.
- **Altering plans and recommendations:** the acid test of good scenarios is that working with them changes the vision or plan that was proposed before the exercise. If one goes out by the same door that one went in, then the scenarios were probably too remote to have been useful.

5 Methodology

This methodology chapter describes a three-step process of bringing forward a new research agenda:

A) Foresight state-of-the-art
B) The foresight process
C) From challenges and opportunities to a research agenda

5.1 Foresight state-of-the-art

The first step of the overall process has resulted in a state-of-the-art overview of fisheries and aquaculture foresight analyses world wide. The bibliographic overview of (potential) factors driving the system challenges and completes a factor list built by the consortium partners during their own foresight process.

This overview also helped later in the FEUFAR process by providing insights of past trends and future developments analysed in other foresight exercises. This to some extent alleviated the documentation phase in the FEUFAR scenario-building process, by updating past development of some drivers.

The overview of other foresight studies performed world wide on fisheries and aquaculture was completed according to the template below, decided during the initiation meeting of the project:

FORESIGHT IN FISHERIES AND AQUACULTURE

1. **Title – Report title**
2. **Identifying short title**
3. **Author(s)**
4. **Source (book chapter, FAO Report, etc) and date**
5. **Geographic scope**
6. **Focus or disciplinary scope**
7. **Stated objectives of the study and the target audience**
8. **Time horizon**
9. **Method employed for the analysis**
10. **Consultee involvement**
11. **Is there a list of drivers, and if so, what are the main ones? Is there a relationship with earlier work, e.g. climate change scenarios? And what is the structure of the scenarios – are they mutually exclusive?**
12. **Is there any addressing of catastrophes/extreme events?**
13. **Originality or USPs (unique selling points)**
14. **Were original research or research drivers included**
15. **What happened next – e.g. are there recommendations, and were any of them taken up?**

This literature review of foresight analyses was performed between months 1 and 5, and was presented and discussed during the expert meeting in May 2007.

5.2 The Foresight process

For the Foresight process in FEUFAR, we built and used scenarios for identifying and assessing key opportunities and challenges. The scenario-building consisted of six steps:

1. **Define** the problem, boundaries, and horizon: initiation meeting
2. **Identify** key variables and their relationships
3. **Build** different hypotheses for each driver
4. **Explore** possible evolutions by assembling hypotheses (two steps)
5. **Outline** possible future scenarios and the paths to them
6. **Identify** the uncertainties, challenges and opportunities that research may answer

Generally, different stages of a scenario-building process are addressed during meetings scheduled for the purpose. However, because the FEUFAR project had limited resources, the number of project meetings was also limited. Therefore, a strong specificity of the process was that some stage validations among project partners were done through the project website and by e-mail, requesting each project partner to react to or to comment on the proposals at each stage.

5.2.1 Definitions

The project goal was to define the research required in the medium term (10 years) to allow exploitation and farming of aquatic resources (finfish and shellfish) in the context of key challenges and risks for meeting sustainability requirements. The project's target was to contribute to implementation of a future European Maritime Policy and to further strengthen the European Marine Research Area through better anticipation of research needs within fisheries and aquaculture. With this in mind, the boundaries of the foresight system were defined more precisely by the consortium partners during the initiation meeting.

Time: The time-frame was set to 2020. By looking 10–15 years into the future, the time-frame for the scenarios is deemed long enough for important changes to materialize, while not being so distant that the sense of realism and relevance is lost. We therefore asked how wild fisheries and aquaculture might look in 2020, to determine the most effective research priorities for the next 10 years to meet the different futures envisioned in the scenarios.

Geography: This was defined as the seas and oceans bordering Europe, including overseas European territories and long-distance fleets. The team decided, in discussion with the Commission, that the main focus should be on marine fisheries and mariculture. Therefore, although inland fisheries and freshwater aquaculture are mentioned in terms of common issues (global fish supply, feed demand, genomics, etc), inland freshwater ecosystems are not considered in the system.

Who to include: A broad array of input was secured through the involvement of experts and stakeholders from both fisheries and aquaculture. An expert committee was formed, consisting of representatives of the research community who could assist in providing feedback to the analyses made within the project. Stakeholders, representing industry and management areas on regional, European or international scale, as well as environmental and consumer interest, were invited to contribute to project workshops, to have interim findings presented, and to give feedback.

5.2.2 Identification of key variables and their relationships

Here we clarify what is meant by variables, drivers and subsystems, and describe how we identified the key variables and the possible relationships between them.

Variables and subsystems

Definition: *Variables* or *drivers* are the parameters that describe or influence a system. They are always a mix of factors and actors acting on or affected by the factor. A trend is not a driver, but rather an hypothesis.

The difficulty in determining the drivers of the system is to find the right mesh (precision) for the topic being addressed in order to achieve a list that does not exceed around 50 drivers. Identifying the list of key drivers always starts with the question: what drivers influence the evolution of the wild fishery and of aquaculture by 2020?

We considered drivers at several levels. Some drivers, termed *internal drivers,* describe the fisheries and aquaculture sector, for example fisheries production, fish demand, fisher demography, use of fishing technology, the number of boats in the fleet, fishery regulation, etc. However, the evolution of fisheries and aquaculture is also influenced by *external drivers* such as climate change, that might influence the productivity of the ocean, population growth or purchasing power development, that will influence public demand for seafood.

The drivers describing the wild fishery and aquaculture and the ecosystem within which each operate were grouped into subsystems, the size of which was limited to a manageable number of 5–10 drivers each.

Definition: A *Subsystem* is the list of drivers attached to a more precise domain, assembled by proximity. Proximity is defined as having a direct logical link (i.e. “climate change” with “ocean productivity”) or involving the same stakeholder group, often with a group of global context drivers. Together, different subsystems describe all relevant aspects of an area under investigation, in this case the European fisheries and aquaculture industries.

The future of wild fisheries and aquaculture can be found in many different subsystems, and at the initiation of the project we considered the following subsystems to be likely:

Possible subsystems:
- Context: global warming, oil prices, world governance, risk management, etc
- Demand for fish and sea products (quantity and quality of material as food, and in terms of raw materials, pharmaceuticals, etc.)
- Fishery and aquaculture technical and technological processes (growing, catching, processing)
- Fishery and aquaculture activity and economics
- Fishery and aquaculture management and regulation
- Socio-economy of coastal regions
- Ecosystem: water quality and environmental features (foodweb features, fish behaviour)
- Organization of research, including collaborative research

Determining the key variables and subsystems

The drivers are the bricks in the system. The team had an in-depth and lengthy discussion on the drivers we deemed relevant, in order to clarify overlap and differences among them. This was important for their functioning as building blocks for the scenarios, but also for managing the complicated tasks of driver description and documentation. With limited resources available, the team spent a lot of effort in keeping the extent of the system manageable. A system size of, say, 50 drivers was considered manageable during the time-frame of the project, but ending up with, say, 80 drivers, we risked not being able to describe the drivers in sufficient depth and detail.

Identification of drivers was performed in three steps. First we identified likely drivers. Second, we invited experts on fisheries and aquaculture to validate and refine our list. Finally, we completed and refined our list with the help of stakeholders. This three-step process is described below.

Team effort on driver identification: A first list of drivers was assembled during the FEUFAR initiation meeting held in early February 2007. This list, including a first attempt at assembling drivers into subsystems, was taken home by the partners to be completed (each partner indicating the missing drivers influencing fisheries and aquaculture). The team divided the drivers among them, with the aim of defining the drivers in 2–3 lines and listing indicators for each driver. The definition of each driver, meanings having been clarified to all, was agreed upon by the team by e-mail communication. Indicators for all drivers were also developed, to show how the drivers would differentiate future hypotheses: e.g. "labelling" drivers might mean the number of labels on seafood in Europe or worldwide, the evolution of stakeholders producing labels, and what issue is being labelled (origin, nutrient quality, fished/farmed, etc). Therefore, the definition and indicators for each driver at this early stage allowed new (clearer) wording of the variable and further system simplification. Such thorough discussion within the team paved the ground for the next steps, the validation of the drivers list by experts and stakeholders.

Expert meeting (21 –23 May 2007): Expert partners were asked to discuss and prioritize the list of drivers and indicators drawn up by the project partners. The experts were researchers, so it was assumed that they would have more or less the same idea of the wild fishery and aquaculture systems (the drivers) as the project partners; this assumption, however, was not expected to hold for stakeholders.

To avoid the experts invited being coloured by the team's perceptions, they were requested to build their own list of drivers from scratch, formulating their own groupings and building them into subsystems. After the initial brainstorming, the list of drivers list was discussed and improved upon. At the end of the workshop, this list was merged into the team's list. Some new drivers were added to the team's list, some were omitted, some were given new definitions or scope and some were placed into other subsystems. For the *Stakeholder workshop*, the same process was repeated, but this time resulting in fewer changes.

Experts were asked whether they would wish, later in the project, to contribute to the documentation of the drivers and the development of the hypotheses. The meeting was also used to present, question, add to, and discuss the literature review performed under WP1.

Stakeholder workshop (25 –27 June 2007): The stakeholders were asked to determine the drivers most likely influencing the system. They were also told to start with a blank sheet, so that their representation of the system drivers could be compared with that of the project team and the experts. The two representations of the system were discussed and compared, and by the end of the workshop, the final set of drivers and subsystems was agreed upon, taking the stakeholders' vision of the system into account.

The system definition was then enacted into an internal document. Each driver was then described and discussed, and for each driver, several hypotheses were derived. The drivers and the hypotheses are found in report 3: System and Drivers; trends and developments.

This second driver/subsystem description, along with the set of definitions and indicators for each driver was then sent to the team, asking for comment, question and finally common validation.

Relationship among variables, and system simplification

A rational method known widely as *structural analysis* can be used to study the relationships among drivers by quoting the influence of each driver on the others. The analysis leads to an influence–dependence graph of the drivers of the system, enabling one to retain only the most influential drivers in the system for the study. The most dependent ones are results, so can be described in the resulting scenarios and may be disregarded as drivers. However, the method is time-consuming in terms of meetings. Consequently, a fast-track method was used to decide by reasoning and argument which would be the most influential drivers (present and potential), and to retain only those that were most important.

Once all drivers identified by the team had been defined, the system (drivers and subsystems) was reworked:

- to ensure that drivers covered complementary topics;
- if needed, to propose reformulation of certain drivers;
- to propose system simplification, deleting drivers, to end up with some 50 drivers:
    - drivers that were roughly the same were reformulated to encompass the essence of both,
    - by deleting some drivers because they were a consequence of others, so appearing just in the scenarios,
    - because they might be argued as having a secondary influence;
- to make a new proposal for the subsystem assembly;
- to show the logical links among subsystems.

5.2.3 Different hypotheses built variable by variable

This stage lasted from July to November. In order to build future hypotheses in 2020 for each driver, we had to understand the dynamics of each. Therefore, for each driver, we had to answer several questions in order to build our hypotheses about the future:

1) How did that driver develop over the past 20 years or so, and why?
    a. what indicators can we use to trace this development?
    b. what data and time-series are available to prove our point, and how dependable are they?
    c. what drove this evolution?
    d. which actors influenced the driver, and who was affected by it?

2) What is the trend in development or its logical extrapolation? This trend in development was taken as a first hypothesis.

3) Are there potential breakpoints that could block or change the trend in development? Such potential breakpoints can be thresholds, e.g. market saturation, threshold triggering cascade effects (such as regarding climate change), and the minimum biomass for fish stock renewal ability. However, the possible influences may also include innovation, local circumstances or a "weak signal" that could be generalized (a very local way of managing or regulating fishing; a traceability device used for high tech purposes such as defence or research that may have mass market application, etc.). Another influence could be a change in the (game of) actors, such as new alliances or new stakeholder(s) influencing the driver. Taking into account a host of possible influences made possible the construction of hypotheses other than the trend observed.

The foresight literature review (Work Package 1) and the methodology followed during stage two of the scenario process (describing the system) were used to facilitate understanding of the documentation needed in this hypothesis-building process:

- drivers documented in the literature review (WP1) were updated (i.e. rethinking the hypotheses);
- the effort put into understanding and defining the drivers and their possible indicators during the previous stage of the process allowed the team to focus directly on the documentation of past development and to draft hypotheses (step 3 and following, in the template below) during this stage.

Documenting the drivers

For each driver, the team set out to document the driver according to the template below:

1. Definition
2. Indicators
3. Past evolution
4. Hypotheses (future): hypotheses are argued (threshold, actors, etc) and given a name
5. Actors identified
6. Source

Author signature / revision number

Documentation for the drivers was developed between July and September 2007 and shared among participants. Each template was completed and placed on the project website as soon as it is had been written, so that all project members could access it. A first draft was available to the team on the project site by 1 October 2007. Therefore, everyone was able to comment on the documentation and hypotheses for the driver templates written by other project partners during October, allowing all inputs to be commented upon by everyone.

It was considered crucial that the hypothesis be named and that its describer signed it as author. Then, each author took into account comments from the rest of the team and personally edited the second draft. Note that an hypothesis is a *possible* vision of the driver in 2020, not a *desirable* vision. The different hypotheses for a single driver were not necessarily compatible.

The project team version of the templates and hypotheses for each driver were finalized by mid October, and hypothesis tables were then prepared subsystem by subsystem, in time for the late October meeting of the group. At that meeting, all drivers and their hypotheses were discussed in full again, and comments were again taken up by the author of each before final acceptance of each driver. In early December, given their importance, all drivers were thoroughly edited (grammar and content) by two team members, and the document “Trends and Developments” was made available on the website before Christmas.

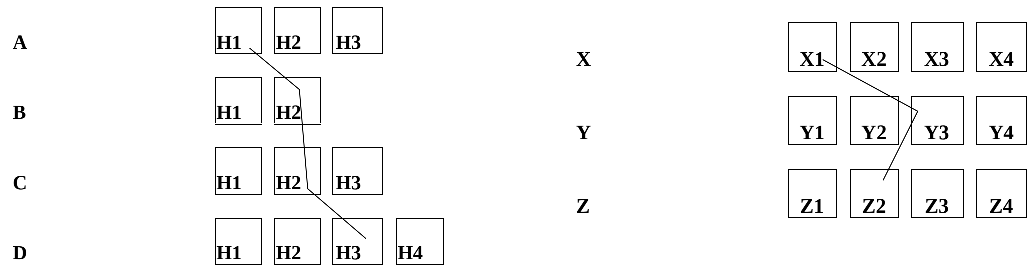
5.2.4 Possible evolutions explored by assembling hypotheses (two steps)

Most of the creative part of this two-step process, i.e. assembling hypotheses to build scenarios, was carried out during formal meetings, and the time between meetings was dedicated to writing up the scenarios. The global process can be summarized as follows:

Micro-scenarios subsystem by subsystem, to Global (macro-)scenarios

Subsystem X

Key variable Hypotheses Subsystem Micro-scenarios



Combined hypothesis exploration: microscenario X1, X2….

Micro-scenarios X1, X2…. become the hypothesis for the global system

Micro-scenarios

An expert workshop on micro-scenarios was held in late November 2007, and to prepare for this meeting, one member of the consortium developed the micro-scenarios for one of the subsystems as a demonstration of the process of construction. Them we allowed half a day to construct micro-scenarios for each subsystem. To facilitate instruction and to guide the expert workshop in the creation of micro-scenarios, micro-scenarios were built by the team for 3 subsystems at a one-day meeting prior to the workshop (note that this, however, was only for exemplification purposes; these micro-scenarios were not used later in the process). Then, during the expert meeting, several groups worked in parallel to build micro-scenarios for all subsystems.

At the end of the micro-scenario workshop, an attempt was made to assess collectively what were the drivers or their hypotheses that allowed one to switch from one micro-scenario to another. These hypotheses are levers to move from one situation to another. Following that workshop, the project team shared out the writing of the micro-scenarios for each subsystem, with a short name being given to each micro-scenario. This writing was done before Christmas 2007 and placed on the project website for project partner reading and validation. This then allowed the tables to be prepared for the global (macro-)scenario task scheduled for March 2008. The micro-scenarios were circulated to all workshop participants, and also made available at the project website.

Global (macro-)scenarios

Global (macro-)scenarios were constructed at a combined expert and stakeholder workshop in March 2008. Experts and stakeholders were told to assemble hypotheses (in fact, micro-scenarios), with different logical consistence, to construct an image of the wild fishery and aquaculture system by 2020. They were also requested, after constructing this final image, to describe the path from 2008 to these different final visions, to develop a storyline for the development of the scenario. From a list of micro-scenarios, the experts and stakeholders sat together in five groups to develop the macro-scenarios. The project team was encouraged to synthesize some 24 (micro)scenarios, and came up with a grouping of four, which after further discussion between all (not just the groups) was rationalized to a final list of five realistic scenarios. These formed the basis of the final scenarios used.

In this part of the project, it was considered vital that the number of scenarios did not exceed four or five, in order to present only the most divergent paths to the future and to allow readers to understand quickly the specific dynamics of each. One must remember here that the purpose of a scenario is not to depict exactly what the future will be (most likely, it will be an intermediate between scenarios), but to show, by comparing scenarios, the plan of action for different stakeholders, and to highlight different possible opportunities and challenges for fisheries and aquaculture. Therefore, the scenarios had to be slightly caricatured to clarify the issues in each storyline.

5.2.5 Possible futures and their paths

A first draft of the global (macro-)scenarios was produced in April 2008 and placed on the website to allow the team to comment and to add detail before the final expert and stakeholder workshop, which had been scheduled for June 2008.

The scenarios describing the final images and the paths to the anticipated situations were presented to experts and stakeholders in June. At that meeting, they were asked to discuss the scenarios during a workshop, and to comment on whether they found alternative scenarios to be very different, on how much credibility they gave to the different scenarios and, very importantly, to say whether they could see alternative paths through some of the scenarios.

5.2.6 Uncertainties, challenges and opportunities for research to answer

At the outset of the final expert and stakeholder workshop in June, experts and stakeholders were asked to derive from the scenarios what would likely be the main challenges and opportunities for fisheries and aquaculture that might be answered by future research.

5.3 From challenges and opportunities to a research agenda

The final scenarios, along with a list of the challenges and opportunities for fisheries and aquaculture, are documented in the report from the final expert and stakeholder workshop. Identification of the challenges and opportunities from the scenarios is the basis of the next step, to consolidate views on a research agenda, and permitted the project to move from Work Package 2 (WP2) to WP3. Therefore, Work Package 3 was initiated in June during the final expert and stakeholder workshop.

Based on the final scenarios presented to them, the experts and stakeholders at the final expert and stakeholder workshop in June 2008 were asked to highlight the major challenges and opportunities under each scenario, and to draft out a realistic research agenda based on the challenges and opportunities. Some scenarios obviously appeared more appealing than others. However, it was deemed as important for stakeholders to specify research to preclude moving towards (or alleviate) unsustainable scenarios as to promote sustainable scenarios. Therefore, all scenarios were crucial to the dialogue, especially in terms of identifying challenges and opportunities. Specifically, the uncertainties around the consequences of specific strategies (parts of scenarios) on the business or the ecosystem led to new research topics being tabled.

To develop strategic options further, the workshop differentiated at the level of each scenario the links with both European and external context strategies. By confronting different options available to European actors illustrated within the scenarios in different contexts, we stressed the area of potential action for Europeans, what was their capability of meeting such challenges, and hence their strategic options.

Prioritized lists of challenges and opportunities were developed during the process. However, priorities differed according to the criteria used: priorities to meet specific sustainability targets sometimes differed from stakeholder priorities. Another way we found to prioritize was to extract a list of common challenges and opportunities from all scenarios. In elaborating the research needs, we also touched on the different roles and priorities of research institutes, universities and private research organizations in, e.g. biotechnology, processing and pharmaceuticals. We also discussed how a realistic balance between public and private research could unfold in future, according to the priorities we set.

The need to organize and develop new tools was also considered, examples being relevant and accessible databases, mathematical models and experimental infrastructure. Also, suggestions were made for key solutions to improve the conditions for interdisciplinary research, research collaboration and research planning.

5.4 Methodological considerations

To move beyond scenarios, with their corresponding challenges and opportunities, towards research priorities, we had several methodological issues to consider:

- how to allow new and interesting perspectives;
- whom to involve in the process;
- how to avoid pitfalls, such as stakeholders advancing their own personal interests in the process, or drowning new perspectives in discussing known topics that are still not solved?

The first question would be whether the scenarios, and their challenges and opportunities, were a sufficiently robust basis to recommend research priorities. In this respect, the scenarios needed to be

- consistent,
- believable, and
- well described in terms of actors and processes.

The team considered the scenarios needed to fulfil these requirements. An important argument for selecting a scenario approach for this project was that with scenarios it would be possible to prioritize entirely new areas of research. However, that could not happen automatically, because there was a possibility that if today's stakeholders set an agenda, nothing new would transpire from the process. That itself, of course, is a good argument for making the scenario process a broad one. Involvement was therefore a key issue in the whole process. The team believes that solid foundations are laid through involvement, in terms of the perspectives shown and the legitimacy of the process and results. In respect of the different perspectives and legitimacy, we sought to maintain a broad and representative (of many sectors) stakeholder representation throughout the process. Such a consideration was even more important for the final stage, where research priorities were discussed.

The primary stakeholders in shaping a future research policy for fisheries and aquaculture would of course be the fisheries and aquaculture industries themselves, representing the entire value chain and its research community. We therefore asked the questions who would be the long-term stakeholders, and were they different from the stakeholders today? To ensure that potential future stakeholders were heard within the process, other stakeholders, such as consumer organizations and NGOs, some focusing on sustainability and environmental questions, were invited to participate in the overall process. Particular attention was also paid to the involvement of nations not represented in the project team itself, for instance Spain and the Portugal, both of whom have a historical interest in the harvesting of marine resources and, lately, aquaculture.

It was also considered important that the team advanced the need for careful prioritization of research tasks. As new perspectives were advanced, we were prepared for the stakeholders potentially to move into a form of "prioritization mode", perhaps causing new perspectives to be drowned in conflicts of interest among existing topics. This was, we believe, alleviated by insisting that the stakeholders ask themselves "what are the *interesting* perspectives?", in order for them to be able to discuss the original thoughts being advanced. This was important for making them explore the *possible*, as well as the desirable and likely, futures.

In trying to develop research priorities, the team looked at whether they should represent a consensus among stakeholders. Indeed, was that possible? Or perhaps, we thought to seek ways of handling different or opposing interests? Ultimately, the project team found this to be less of a problem than anticipated, possibly because in shaping the process, we took the dynamics of the different actors into account. The process of developing the research priorities was therefore handled in a very structured manner:

- Experts and stakeholders were divided into groups, each group working with s single scenario. They were asked to come up with the most relevant or important research tasks, in their opinion, to be deduced from the scenario in question.
- They were also asked to draft research tasks aimed at following a desired course of development, and (as important) the tasks needed to preclude unwanted developments.
- From a long list of tasks, re-arranged groups of the same representatives at the meeting were then asked to prioritize among the tasks.
- Finally, and very importantly, they were asked to argue the case for their priorities in front of the whole workshop, including the contract team. In this manner, every

argument in favour of a research topic had to be aired in front of a group, and no one person was able to advance his/her own personal agenda.

Input from the stakeholders was provided to the project team in written form, including from stakeholders not able to join the workshop, as a form of wish list for future research, but this input was used mainly as a reminder that the topics in question had been taken into account in the discussion. It was considered important that no topic would form part of the research agenda other than as a result of discussions in workshop groups. The research agenda, divided into five areas of research, was finalized on the last day of the final workshop by the project team, and circulated among workshop participants for comment.

5.5 A time-line of the foresight process

In this final part of our methodology chapter, we provide a brief summary of the steps and the progress in the foresight process.

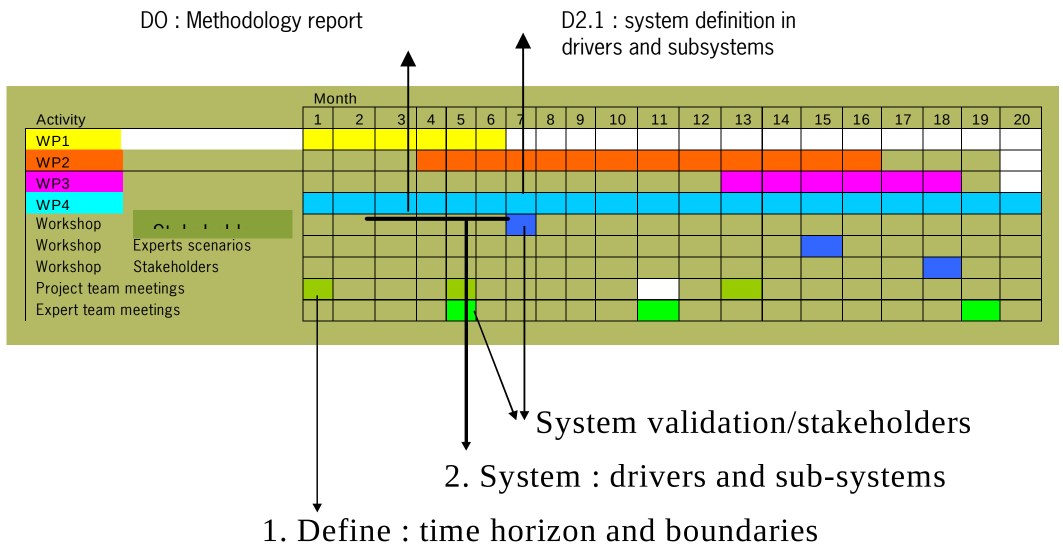
5.5.1 Stages 1 and 2, describing the system

Stage 1: one of the objectives of the start-up meeting in Heraklion (Crete) from 5 to 7 February 2007 was to define the boundaries of the system.

Stage 2: defining drivers and subsystems lasted from month 2 to month 6, and ended with the stakeholder workshop in month 6.

A more detailed overview of stage 2 is listed below:

- At the initiation meeting of the project in early February 2007, a first list of drivers was drafted and assembled roughly into subsystems.
- The subsystem/driver table was sent to partners for additions, comments and rethinking, and returned for finalization shortly thereafter.
- A short template asking for a definition and indicators was circulated to team members in late February, and driver documentation tasks were split among the team. The completed template with definitions and indicators was delivered by 15 March.
- A synthesis of the driver system was then circulated among the team during early April.
- This synthesis was commented upon and questioned by the team, so that the whole consortium could agree on a description of the drivers during early May.
- A short methodology report and plan was made available on the project website for experts and stakeholders in mid-March.
- An Expert meeting was held from 21 to 23 May in Brussels, to discuss the literature review and the driver system.
- The Stakeholder workshop of 25–27 June, held in the Netherlands, compared the description of the system through the drivers within the system outlined by the project team, and fresh input was made as appropriate.
- System definition ended in late June, and the report was available in July 2007.



5.5.2 Stages 3 – 6: hypotheses, scenarios and stakes

The system was defined (in terms of drivers and subsystems) during late June, and a template (with definition and indicators already documented for most) for the driver documentation was sent to partners during early July 2007.

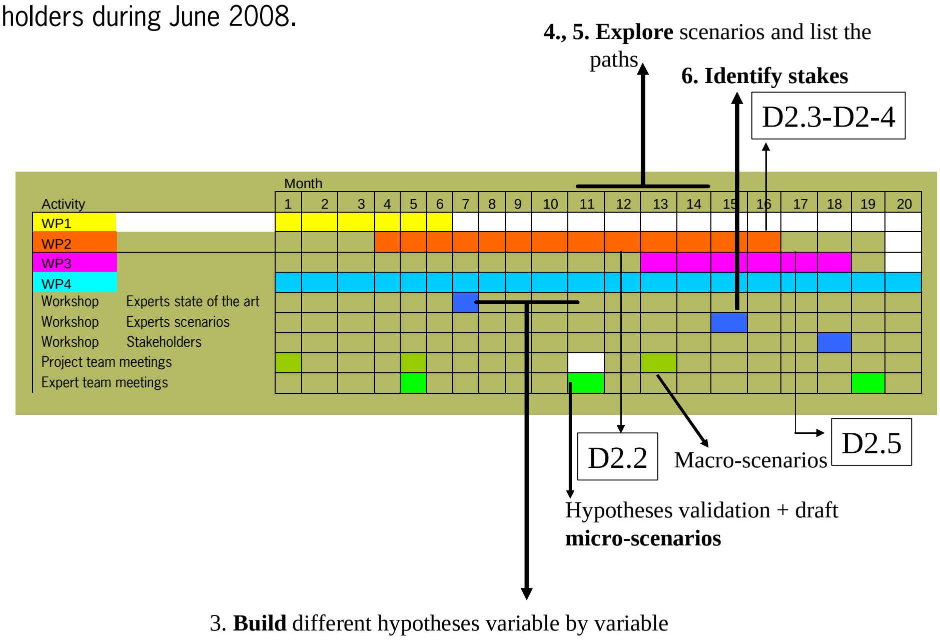
Documentation of the drivers was finalized through to the late October team meeting, and it was carefully reviewed, edited and made available on the website in mid-December 2007.

The expert meeting and the project meeting in early November 2007 allowed the project team to finalize their hypotheses and to build micro-scenarios subsystem by subsystem.

The drafting of micro-scenarios was shared among partners and made available on the project website before Christmas 2007.

A first draft of global (macro-)scenarios was drafted and made available on the project website for team/partner validation, comment or addition in April 2008.

The global (macro-)scenarios, ratified by the team, was then discussed with experts and stakeholders during June 2008.



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