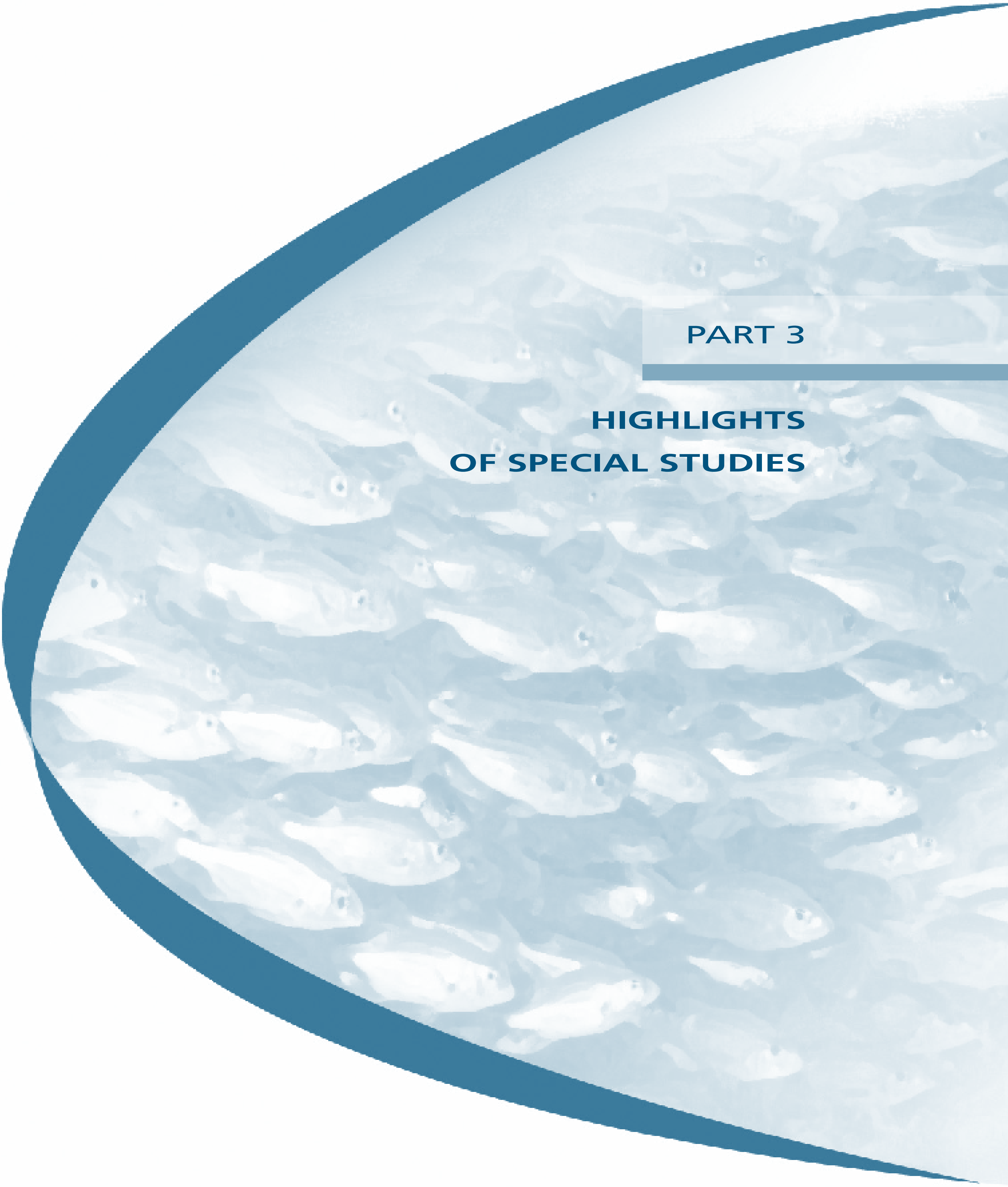
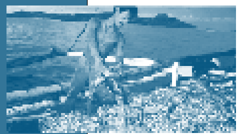
PART 3

HIGHLIGHTS OF SPECIAL STUDIES





HIGHLIGHTS OF SPECIAL STUDIES

Effects of fisheries management policies on fishing safety

Commercial fishing has always been a dangerous occupation. Although it is inherently dangerous, many would argue that the degree of danger is a function of fishers' choices about the risks they take, such as the weather they fish in, the boats they use, the rest they obtain, and the safety gear they carry. Multiple studies suggest that although fisheries management policies are not meant to regulate safety at sea, they do sometimes contribute to safety problems.[1] For example, following interviews with 22 experienced boat owners, captains and crew in the fishing community of New Bedford, the United States of America, about their attitudes on safety at sea and fisheries management, one study reported: "Approximately two-thirds rated fisheries management regulations as an important factor that affected safety at sea. In fact, for over half of the fishermen, fisheries management was believed to be among the most important issues that impact safety at sea. Fishermen reported several problems in which increased dangers at sea were attributed to management regulations designed to protect various fisheries."[2]

Despite a variety of evidence that fisheries management affects safety, there has been relatively little systematic analysis of how management policies affect safety or the extent to which changes in management can affect safety.

In order to understand more fully the relationship between fisheries management policies and fishing safety, FAO and the United States National Institute for Occupational Safety and Health developed a study with the purpose to document globally the relationship between safety at sea and fisheries management policies and to provide practical guidelines for fisheries managers and safety professionals on how they can work together to make commercial fishing safer.[3]

METHODS

FAO contracted researchers to prepare country-specific case studies on fisheries management and safety in 16 countries and regions. Each case study was reviewed to identify evidence supporting, or refuting, one or more of four hypotheses regarding potential effects of fisheries management policies on fishing safety.

Hypothesis 1: Fisheries management policies have wide-ranging indirect effects on fishing safety. Although fisheries management policies are enacted primarily to achieve resource management and social and economic goals, they may affect fishing safety indirectly by affecting fishers' options (how, when and where they may fish), creating incentives for fishers to make risky choices.

Hypothesis 2: Quota-based fishery management systems are safer than competitive fishery management systems. In competitive fishery management systems, fishers compete with one another for the available fish. In quota-based fishery management systems, managers limit how much individual fishers may catch. Under the latter, fishers may have less incentive to take risks such as fishing without adequate rest or fishing in bad weather. Quota-based fishery management may also result in the use of newer, safer vessels and gear, and more professional and better-trained crew.

Hypothesis 3: Fisheries management policies that are unsuccessful in protecting resources or limiting the numbers of fishers competing for limited resources may affect safety. If the resources are not managed well, fishers are faced with trade-offs between safety and the income they can earn from fishing. Fishers may venture farther offshore and take greater risks. Similarly, if total catches are limited, more fishers participating in a fishery will result in less opportunity for each fisher to earn income. If the number of fishers competing for resources is not limited, then fishers' average incomes may decline, causing them to take greater risks.

Hypothesis 4: Fisheries management can contribute to safer fisheries directly by integrating safety policies with fishery management policies. Fisheries management agencies may require safety equipment, safety training, and/or inspections as a condition for participating in a given fishery. Fisheries developed in remote locations or identified as being particularly hazardous could have additional requirements placed on participants.

Where evidence was found for a hypothesis, the strength of evidence was then evaluated:

Table 14
Study hypotheses

Country/ region	Hypothesis 1 *Indirect effects of fishery management on safety*	Hypothesis 2 *Effects of quota-based management on safety*	Hypothesis 3 *Effects of unsuccessful management on safety*	Hypothesis 4 *Integration of safety policies with management*
Argentina		Empirical and anecdotal		
Chile		Empirical		
European Union	Hypothesized			
France		Empirical		
Ghana			Hypothesized and anecdotal	Hypothesized
Iceland	Hypothesized	Anecdotal		Empirical and hypothesized
Japan	Implicit			
Malawi	Hypothesized and anecdotal		Hypothesized effects	Hypothesized effects
New Zealand	Empirical and anecdotal			
Pacific Islands			Hypothesized and anecdotal	Hypothesized and anecdotal
Peru				Hypothesized and anecdotal
Philippines	Hypothesized and anecdotal			Hypothesized and anecdotal
Spain	Hypothesized and anecdotal			Hypothesized and anecdotal
Sri Lanka	Empirical and hypothesized			Hypothesized
Sweden	Implicit			
Thailand	Anecdotal		Anecdotal	

Notes: Shaded cells indicate that the hypothesized potential effect is not relevant for the fishery. Blank cells indicate that insufficient information was provided in the study to draw any inferences about potential effects.

- Empirical evidence was obtained by an analysis of quantitative data.
- Anecdotal evidence was based on observations by fishers or managers.
- Hypothesized evidence was based on reasoning by the study authors about potential effects.
- Implicit evidence was deducted from information presented by study authors that suggests potential effects that were not specifically identified or discussed in the studies.

RESULTS

Between May and August 2008, researchers from 15 countries prepared 16 case studies. Each case study offered some level of evidence for one or more of the four hypotheses (Table 14).

CASE STUDY
Godelman, E. Argentine safety at sea and fisheries management. August 2008.
Carrasco, J.I. The Artisanal Regime of Extraction and its impact on the safety at sea. The case of a Chilean coastal pelagic fishery as an artisanal fishery under transition. 2008.
Renault, C., Douliazel, F. & Pinon, H. Incidence of gross tonnage limitations under the European Common Fisheries Policy. June 2008.
Le Berre, N., Le Roy, Y. & Pinon, H. Safety incidence of the management of scallop fisheries in Brittany and Normandy (France). June 2008.
Bortey, A., Hutchful, G., Nunoo, F.K.E. & Bannerman, P.O. Safety and management practices in marine fisheries industry of Ghana. June 2008.
Petursdottir, G. & Hjorvar, T. Fisheries Management and Safety at Sea (Iceland). September 2008.
Matsuda, A. & Takahashi, H. Present status of the study of safety and management of fishery in Japan. November 2008.
Njaya, F. & Banda, M. Fishing safety and health and fisheries management practices: case of southern Lake Malawi fisheries. June 2008.
Wells, R. & Mace, J. Case study on the relationship between fisheries management and safety at sea. The New Zealand albacore fishery. September 2008.
Gillett, R. Sea safety in the Pacific Islands: The relationship between tuna fishery management and sea safety. June 2008.
Cardenas, C.A. Project artisanal fisheries and survival at sea in Peru. July 2008.
CBNRM Learning Center. Sea safety and fisheries management: tuna fishing industry in General Santos City, Philippines. August 2008.
Seco, B.R. Study of the relationship between safety at sea and fisheries management in the competence of autonomous regions and their influence on the safety of fishermen and fishing vessels and fisheries management in Spain. July 2008.
Hettiarachchi, A. The multi-day fisheries of Sri Lanka: management and safety at sea. June 2008.
Roupe, U. Fisheries management and lobster fishery: a case study on risk and safety from Sweden. August 2008.
Chokesanguan, B., Rajruchithong, S., Taladon, P. & Loogon, A. Safety at sea of trawler and purse seiner in Thailand. August 2008.

Hypothesis 1

Ten case studies provided evidence supporting Hypothesis 1. One of the most compelling studies was a report discussing the hypothesized effects of fisheries management on safety in Iceland, including the special line of dispensation and days of effort. The special line of dispensation allows small vessels to fish with baited hooks and lines rather than nets to catch 16 percent more than their allocated individual transferable quota (ITQ) limit without incurring any penalty. However, the vessel is required to return to the same port from which it sailed within 24 hours. This restriction may result in the vessel not being able to go to the nearest port to avoid dangerous weather. Days of effort resulted in a potential safety problem because, when a vessel sailed from port, one whole day was deducted from the total allotment. This resulted in an incentive to stay out at sea if problems were encountered or in deteriorating weather. However, in 2003–04, this rule was changed and the hazard was eliminated by measuring effort by hours started.

Another report from the European Union discussed the safety effects of restrictions on the gross tonnage of fleets. Member States are obligated to reduce fishing capacity as measured by gross tonnage and engine power. The authors argue that gross tonnage restrictions have important negative impacts on safety owing to the ageing fleet and restrictions on new vessel construction. The physical characteristics of older vessels may make it almost impossible to install technological advances that protect workers, and constraints placed on new vessel construction do not allow modern construction methods to be used. Similarly, the Spanish authors suggest that the vessel-size limits imposed by the European Union result in vessels carrying equipment that makes them unstable in bad weather. The Spain case study also expresses concern over multiple and overlapping jurisdiction resulting in an overly complicated system.

In addition to the above examples, the case report from New Zealand discussed risks that fishers take in preparation for implementation of a quota-based fishery management system. When implementing a quota-based management system, shares are sometimes based on fishers' catches during a specified period (the "catch history years"). The financial benefits of catching fish during this period are greatly multiplied by the right they may confer to catch more fish in the future. The phenomenon of "fishing for history" is widespread in fisheries where there is a perception that managers may impose quota management. The authors from New Zealand expressed concern over risks that fishers take while "fishing for history".

Hypothesis 2

Four case studies provided insights about whether quota-based fishery management systems are safer than competitive fishery management systems. The case study from France supported this hypothesis. The study compared three scallop fisheries where the local fisheries committees have adopted different management regimes for controlling fishing effort. Safety in scallop fisheries is of particular concern – scallop fisheries account for less than 6 percent of full-time equivalent fishers in France but account for more than 15 percent of fishing fatalities. In the Bay of St. Brieuc, management regulations result in a 45-minute race to fish. In contrast, in and off the Bay of Seine, a

Table 15
Comparison of accident rates in French scallop fisheries

Fishery	Type of management	Total accidents 2000–05	Yearly average accidents	Yearly exposure time	Frequency rate
		(No.)	*(No.)*	*(Hours)*	*(F)**
Bay of St. Brieuc	Competitive	80	13.3	108 900	122
Bay of Seine	Quota-based	227	37.8	638 600	59
Off Bay of Seine	Quota-based	313	52.2	2 860 000	18

* F = (yearly average accidents/yearly exposure time) × 1 000 000.

daily quota system without time limits is enforced. The study reviewed the respective scallop fishing fleets including the vessel type, gear and fisheries management regulations. They also estimated the population at risk, reviewed accident data, and calculated accident rates. The results show strong empirical evidence that daily catch quotas resulted in fewer occupational accidents than the competitive fishery because they provided fishers with the option to fish more safely.

Much higher accident rates were found in the competitive scallop fishery than in the two quota-based management fisheries (Table 15). The authors concluded that the major contributing factor to these differences was the management regime.

The study from Chile contrasted different strategies for using fishing quotas. During the first period (2001–03), global quotas were established for both industrial and artisanal fleets, and industrial fishing was banned from the Artisanal Fishing Reserved Area. Increased resources in the artisanal sector led to substantial growth in the artisanal fleet during these years, which encouraged a race for fish. During the second period (2004–07), the "Artisanal Regime of Extraction" was implemented; shares of the global artisanal quota were allocated to ad-hoc organizations of fishers based on groups' past participation and landings in the fishery. Compliance with the global quota improved, which contributed to a lessening of the race for fish and vessel overloading. The rates of fatalities, injuries and search and rescue (SAR) incidents show that safety problems increased during the first period but decreased during the second period.

Although the case report from Iceland did not evaluate the ITQ programme specifically, the authors did note that the ITQ system in Iceland "opened an opportunity for consolidation and modernization of older, less efficient and safe vessels" and that it contributed to a significant decline in the numbers of vessels and fishers. Under the quota system, there has been a significant decline in total SAR and medical evacuation missions and fatalities.

Hypothesis 3

Four case studies (those for Ghana, Malawi, Pacific Islands, and Thailand) discussed situations in which fisheries management agencies lacked the capacity to limit effectively catches and/or the number of fishers participating and provided evidence for Hypothesis 3. In all of these reports, economic pressures on coastal populations, for whom fishing is an important traditional activity and employer of last resort, led to increasing catches, which led to depletion of near-shore resources. This problem was sometimes aggravated by uncontrolled catches by larger industrial vessels, both domestic and foreign, operating (often illegally) in the same waters. As near-shore resources were overfished and declined, fishers fished increasingly farther offshore, where they faced greater risks.

Hypothesis 4

Several case studies discussed Hypothesis 4 and listed the potential benefits for safety if managers placed safety requirements on fishery participants. A study that reviewed the accident and fatality data from fishers between 1991 and 2007 made the strongest argument for this. The authors discussed three features of the Icelandic management system. Most importantly, in Iceland, a fishing licence is only issued when minimum safety equipment and crew training are achieved. The authors concluded that mandatory requirements for safety training, equipment and awareness have increased safety. From 1991 to 2007, SAR missions decreased by 50 percent. The Icelandic authors state that: "the system contributed to the increased safety through placing requirements on equipment and training, resulting in a lower accident rate."

DISCUSSION

The case studies provide evidence of how fisheries management policies can affect safety. Many case studies provided persuasive arguments for change. They add to a body of existing literature that demonstrates that fisheries management policies have wide-ranging effects on fishing safety. The FAO Code of Conduct for Responsible Fisheries (the Code) provides a necessary framework to ensure sustainable and safe fishing.[4] In FAO Fisheries Circular No. 966,[5] the authors argue that: "safety at sea should be integrated into the general management of the fisheries in each country." They further state that regulations should ensure "the safety and well-being of the fishermen, as well as sustainable utilization of the fishstocks."

Although fisheries management policies may be enacted primarily to conserve resources and achieve economic and social goals, fisheries managers need to be aware of how management affects safety. They need to consider whether management policies that negatively affect safety are necessary, or whether conservation, economic and social goals can be achieved through regulations that allow and encourage fishers to fish more safely. Safety in the fishing industry cannot be separated from fisheries management. To improve fishing safety, fisheries management personnel and fishing safety professionals should work together to identify solutions to meet all goals. Policies that result in fishers being forced to choose between risk-avoidant situations and maximizing profits should be examined. Most case studies (63 percent) provided some evidence of how fisheries policies affect safety (Hypothesis 1). Management regulations that negatively affect safety need to be modified to protect fishers.

Four case studies reviewed how quota-based fisheries managed policies affect safety (Hypothesis 2). They reported mixed results. One of the underlying goals of quota-based management systems is to improve safety. In theory, quota-based systems may reduce fishers' incentives to take risks such as fishing without adequate rest or fishing in bad weather. Thus, replacing a competitive derby fishery with an individual fishing quota may remove some incentives to take risk.

However, this does not in itself guarantee that such risks will not be taken. It is overly simplistic to argue that quota-based fishery management systems are always or necessarily safer than competitive fishery management systems. Therefore, it is not quota-based management in itself that makes a fishery safer or less safe. Rather, it is how quota-based management affects those who participate in the fishery, how they participate, and the conditions and incentives under which they participate. These effects may vary widely across quota-based programmes depending on how the programmes are structured and on other factors affecting the fishery, ranging from the marine environment to the market.

It is clear that under certain conditions quota systems can reduce the risks in a given fishery. A report on the comparative analysis of regulatory regimes[6] states: "Some fisheries have experienced significant improvements in health and safety following the implementation of IQ programs, including the Nova Scotia offshore fishery ..., the Alaskan halibut and sablefish fisheries ... and the British Columbia geoduck fishery ...; others have maintained relatively high accident and fatality rates under the IQ system, such as the surf clam and ocean quahog fisheries of New England ... and the national fisheries of Iceland ... and New Zealand".

Case studies reviewing Hypothesis 3 found evidence that if fishery resources are depleted, or competition for limited resources becomes more intense, fishers will take greater risks, such as fishing farther offshore, to seek a living. The challenge faced by managers in addressing safety problems extends to balancing resource protection, economic development and social goals such as access to economic opportunities in an occupation that, in many places, is one of last resort. It is clear from these case studies that fishery managers in developing countries face very serious challenges, and that fishers in these countries may face much greater risks than those in most developed countries. These risks are less likely to derive from constraints imposed by fishery managers than from the inability of fishery managers to constrain harvests and access to fishing by coastal residents willing to take risks in pursuit of their livelihoods.

Half of the case studies provided examples and ideas about how fisheries management can contribute to safer fisheries directly by integrating safety policies with fishery management policies (Hypothesis 4). Where practical, fisheries management policies should incorporate strategies to reduce hazards and make fishing safer. A Canadian study[7] concluded that: "If properly facilitated, many aspects of safety can be enhanced through the fisheries management definition without compromising other management objectives. Connecting licenses with competency, safety certificates and vessel seaworthiness may provide a good system of checks and balances for a long-standing problem. Incorporating safety oriented measures into other management procedures such as permitting variations on partnering and quota allocations, could introduce valuable safety practices that makes fishing in small vessels more practical. Before proceeding with these kind of measures however, there would have to be a serious buy in by other players, including fishing industry representatives."

Managers find themselves in a position where they have to attempt to balance multiple objectives under significant uncertainty, with limited resources. Managers should take practical steps and acknowledge that: "Safety at sea must be integrated into the general management of fisheries in all coastal states if safer working conditions for fishermen are to become a reality."[8]

CONCLUSIONS AND FOLLOW-UP

All of the case studies provided some level of evidence for one or more of the four hypotheses. Although most case studies did not empirically measure safety effects, the anecdotal and persuasive arguments regarding the effects of policies on safety cannot be dismissed. Fisheries managers, safety professionals and fishers need to work together in order to develop and coordinate strategies to improve safety and integrate safety into management policies that not only protect the fish but protect the fishers as well.

While the risks associated with commercial fishing cannot be completely eliminated through policy changes, there should not be a conflict between following policies and choosing to be safe. Fishing safety is a complex problem. The significance and persistence of safety problems in fisheries around the world suggests that there are no easy or obvious solutions. Fisheries management is not the only or most important factor affecting fishing safety. However, the case studies reviewed add to the wide range of evidence that fisheries management can affect fishing safety in a variety of ways. It is important to understand what these effects are, and to consider the ways in which fisheries management policies, while continuing to meet fishery management goals, may also be used to make fishing safer.

Future research should continue to: examine relationships between fisheries management policies and safety to identify policies that create incentives for fishers to take risks; identify modifiable factors; and develop policy alternatives. This type of research will help support changes in policy to incorporate safety assessments into fisheries management decisions. This synthesis provides evidence for the significant potential for policies to contribute to improved safety in many fisheries. There is evidence of potential policy changes in the United States of America. In 2011, the United States National Oceanic and Atmospheric Administration (NOAA) initiated an Advanced Notice of Proposed Rulemaking to request public comment on potential revisions to its National Standard 10 guidelines, which state: "Conservation and management measures shall, to the extent practicable, promote the safety of human life at sea."[9] In any country and commercial fishery, continued monitoring of the change in risks is warranted. Improved data collection and coding are necessary to track adverse events by type of fishery for future evaluation.

Food safety remains a critical component for food and nutrition security

INTRODUCTION

Today, food safety remains a major concern facing the seafood industry and it is a critical component in ensuring food and nutrition security worldwide. The production and consumption of safe food are central to any society and they have a wide range of economic, social and, in many cases, environmental consequences. The issue of food safety is even more important in view of the growth in international fish trade, which has undergone tremendous expansion during the last three decades, increasing from US$8 billion in 1976 to a record export value of US$102.5 billion in 2010. Developing countries play a major role in international fish trade. In 2010, their exports represented 49 percent (US$42.5 billion) of world fish exports in value and 59 percent (31.6 million tonnes live weight equivalent) in volume.

In 1994, FAO published *Assurance of Seafood Quality*[10] in response to the growing need for guidance on the subject from Members. A decade later, in 2004, FAO published an expanded and revised technical paper *Assessment and Management of Seafood Safety and Quality*[11] that addressed new developments, especially with regard to food safety and the adoption, internationally, of the Hazard Analysis and Critical Control Point (HACCP) system and risk analysis concepts.

In response to the increasing importance of seafood trade and to the significant changes in the regulatory environment in the last decade, a new and revised FAO technical paper[12] has re-examined the whole area of seafood safety and quality. The study focuses on:

- developments in food safety and quality management systems;
- characterization of the food safety hazards in seafoods and seafood quality;
- implementation of management systems to ensure safe and high-quality seafoods.

The study also analyses:

- the regulatory framework that all food business operators (producers, processors, distribution and retailers) must now operate within – at the international, regional and national levels;
- the probable impact of climate change on food safety, focusing on the most important hazards – microbial pathogens and natural toxins from algal blooms;
- the challenges facing developing countries.

DEVELOPMENT OF FOOD SAFETY AND QUALITY SYSTEMS

In the 1980s, food trade expanded dramatically with more food products crossing national and continental borders. Exports from developing countries increased. At the same time, several food scares, caused by bacterial (e.g. *Salmonella* and *Listeria*) and chemical (e.g. mycotoxins) contamination meant that food safety was an issue of major public concern. This concern was exacerbated during the 1990s by "mad cow disease" and the "dioxin crisis", and these food safety problems forced regulators to rethink food safety strategies, integrating the various components of the value chain and introducing traceability requirements. In the new millennium, food production and distribution have become even more complex and market choices for consumers even wider. The media and consumers have developed a much greater interest in food safety issues following a number of food scares, such as:

- In Germany, a new strain of *E. coli* linked to bean sprouts infected more than 3 500 people and killed 53.
- In the United States of America, a *Listeria* outbreak resulted in 100 cases and 18 deaths, leading to recalls of about 5 000 freshly cut cantaloupes, while a *Salmonella* outbreak linked to peanut butter resulted in more than 500 cases in 43 states and led to recalls worth US$1 billion.
- In China, official figures indicate that 6 babies died and 294 000 were made sick from intentional addition of melamine to various foodstuffs, mainly milk and infant formulas.

Expansion of the food industry and food distribution systems across borders and continents required the development of quality assurance systems to support business-to-business contractual agreements and verification of conformity of food supplies with the specifications. At the same time, the development of bilateral, regional and multilateral trade agreements brought about changes in national and supranational food control systems to harmonize requirements and procedures.

The efforts of the industry and food control authorities were not harnessed in a synergistic way until the advent of regulatory HACCP food control systems. Much still needs to be done to promote complementary systems that will enable the control and prevention of food safety hazards at the source along the supply chain and decrease the reliance on end-product sampling and testing.

RISK ANALYSIS

Food-borne illnesses continue to be a major public health problem worldwide. It is estimated that up to 30 percent of the population in industrialized countries are affected annually,[13] and the situation in developing countries could be worse, although less-developed data systems means quantification is difficult.

The public health significance of seafood-borne illnesses depends on the probability of illness (number of cases) and the severity of illness. The concept of "risk analysis" has become the method for establishing tolerable levels of hazards in foods in international trade and, equally, within national jurisdictions. Risk analysis consists of three separate but integrated parts:

- risk assessment,
- risk management,
- risk communication.

The management and control of food-borne diseases is carried out by several groups of people. First, it involves technical experts assessing the risk, i.e. examining epidemiological, microbiological and technological data about the hazard and the food. Risk managers at the government level decide what level of risk society will tolerate, while balancing other considerations, e.g. the cost of risk management measures and their effect on the affordability and utility of foods. Risk managers in both industry and government are then required to implement procedures to minimize the risk. In the current international food safety management environment, the tolerable level of hazard at the point of consumption is expressed as "food safety objectives". At the industry level, these objectives are met using prerequisite programmes and HACCP procedures.

Risk communication is an integral part of risk analysis and provides timely, relevant and accurate information about the risk of eating food to industry, consumers and public bodies alike. Perception of risk has both technical and emotional dimensions, and risk communication should address both these aspects. Often, non-technical information provided by media, consumer groups or industry captures the attention of the general public exposed to the risk. Risk communication should address the concerns of the public and not dismiss these as irrational.

EXAMPLE OF RISK ANALYSIS LEADING TO DEVELOPMENT OF SEAFOOD SAFETY STANDARDS

At the international level, the Codex Alimentarius Commission (CAC) has the mandate for developing food safety standards. The risk assessment that is required by the CAC for taking risk management decisions are provided by FAO and the World Health Organization (WHO) through joint expert committees such as the Joint FAO/WHO Meetings on Microbiological Risk Assessment and Joint FAO/WHO Expert Committee on Food Additives. In the last decade, there have been examples of FAO/WHO risk assessments leading to the development of Codex Standards. When *Listeria monocytogenes* was recognized as a food-borne pathogen (smoked fish was one of the incriminated commodities), risk managers in some countries adopted a "zero tolerance" approach, while risk managers in others chose a microbiological criterion in terms of colony-forming units per gram of product (this provides a maximum level of bacterial presence) of 100 cfu/g. An FAO/WHO risk assessment showed that predicted illness depends on how many non-compliant products reach the market. Owing to the environmental presence of this organism, achieving zero in all products is technologically difficult, and the risk assessment showed that a criterion would be needed for public health protection in ready-to-eat products, e.g. smoked fish, and that the risk depended on the ability of the product to support growth of the organism. As a result of discussions by the experts, the CAC set a standard of 100 cfu/g in products that do not support the growth of this organism and a "zero tolerance" for products that can support growth.

SEAFOOD QUALITY

While the concepts of risk analysis are clearly developed to ensure food safety, the same approach and thinking can be applied to cover, for example, sensory quality, composition and labelling. National regulations, commercial specifications or international Codex Standards set the specifications for quality.

Similar to the risk assessment process, biological, chemical and physical agents capable of causing quality loss that may affect a particular seafood need to be identified. In addition, a qualitative and/or quantitative evaluation of quality loss needs to be characterized.

SAFETY MANAGEMENT SYSTEMS

As indicated above, there are many pathogens and spoilage agents that can contaminate fish and seafood during handling, processing or distribution, either from

Box 15

The Hazard Analysis and Critical Control Point system and prerequisite programmes

Hazard Analysis and Critical Control Point (HACCP) is a system that identifies, evaluates and controls physical, chemical and biological hazards that are significant for food safety.[1] It is a science-based and systematic tool that assesses hazards and establishes control systems that focus on prevention rather than rely mainly on end-product testing. It not only has the advantage of enhancing the safety of the product but, because of the means of documentation and control, it provides a way of demonstrating competence to customers and compliance with legislative requirements to the food control authorities.

Prerequisite programmes are defined as:

- Procedures, including good manufacturing practices that address operational conditions providing the foundation for the HACCP system (National Advisory Committee on Microbiological Criteria for Foods, 1998).
- Practice and conditions needed prior to and during the implementation of HACCP and which are essential for food safety (World Health Organization, 1999).
- A programme that is required prior to the application of the HACCP system to ensure that a fish and shellfish processing facility is operating according to the Codex Principles of Food Hygiene, the appropriate Code of Practice and appropriate food safety legislation (Codex Alimentarius Commission, 2003).

[1] Codex Alimentarius Commission. 2003. *Recommended International Code of Practice: General Principles of Food Hygiene. CAC/RCP 1-1969, Rev. 4-2003*. Rome, FAO/WHO. 31 pp.

handlers, equipment, surrounding environment or other sources, such as cleaning water or ice.

The advent of the HACCP-based system (Box 15) in recent decades has provided a single system that has now been adopted by international bodies and trading countries and regions to control food safety. However, there are important foundations to be put in place before implementing the HACCP system. International organizations have defined the importance of so-called prerequisite programmes, and this clearly differentiates the prerequisite programmes from the HACCP system – something that is always not fully appreciated by processors in many countries.

Moreover, various bodies have defined what is required in these "pre-HACCP" operations and, while there is overlap, they do differ. This lack of a universally agreed set of operations prior to implementing HACCP has possibly given rise to the lack of consistency in documentation of these procedures when compared with the very structured approach offered by the 12 steps of the HACCP system.

More recently, the International Organization for Standardization (ISO) has developed the ISO 22000 family of standards (ISO 22000 – "Food safety management systems – requirements for any organization in the food chain"). It takes the approach of ISO 9001 as a management system, and incorporates the hygiene measures of prerequisite programmes and the HACCP principles and criteria. In 2008, PAS 220:2008 was developed to cover what were seen to be shortcomings in the prerequisite element of ISO 22000 at the time.

THE REGULATORY FRAMEWORK

The frameworks for ensuring food safety in the international context are provided by: (i) the World Trade Organization (WTO) under two binding agreements (the Agreement on the Application of Sanitary and Phytosanitary Measures [SPS Agreement], and the Agreement on Technical Barriers to Trade [TBT Agreement]); (ii) the Codex Alimentarius Commission (CAC) through various instruments, for example, the Code of Practice for Fish and Fishery Products and the basic texts on Food Hygiene; and (iii) the FAO Code of Conduct for Responsible Fisheries (the Code), especially under Article 6 (General principles, provisions 6.7 and 6.14) and Article 11 (Post-harvest practices and trade), both of which are of particular relevance to fish trade, safety and quality.

For international fish trade, countries have enacted national and regional regulations to control seafood entering or exiting their territories. As more than 70 percent of seafood trade is destined for three main markets (the European Union, the United States of America, and Japan), these markets are important regulatory reference points.

The United States of America has a decentralized system for food safety and quality regulation. There are no fewer than 17 federal government agencies involved in food regulation. The two most important agencies are the Food and Drug Administration of the Department of Health and Human Services, which regulates all food except meat and poultry, and the Food Safety Inspection Service of the Department of Agriculture, which is primarily responsible for meat and poultry. The Environmental Protection Agency regulates the safety of water, while the Agricultural Marketing Service offers product quality and grading services for a fee to all food commodity groups except seafood. Seafood quality and safety services for a fee are provided by the Seafood Inspection Program of NOAA Fisheries within the Department of Commerce. The Department of Homeland Security is involved in ensuring that intentional product adulteration does not occur. The recent Food Safety Modernization Act (2011) is now the guiding legislation for improved food safety in the United States of America.

In the European Union, as the result of a white paper on food safety in 2000, the approach taken in the legislation is to separate aspects of food hygiene from animal health and to harmonize food control across the European Union member countries. A key aspect of the legislation is that all food and feed business operators, from farmers and processors to retailers and caterers, have principal responsibility for ensuring that food placed on the European Union market meets the required food safety standards. The Regulations[14] apply at every stage in the food chain, including primary production (i.e. farming, fishing and aquaculture) in line with the "farm to fork" approach to food safety in the European Union. The Regulations also include provisions for guides to good practice to be developed by industry with support from other stakeholders.

In Japan, distrust of regulatory food safety has been rising among the public. People's growing concern has been triggered by various problems, including the occurrence of bovine spongiform encephalopathy, commonly known as mad cow disease, in 2001. Against this background, Japan has enacted the Food Safety Basic Law, a comprehensive law to ensure food safety to protect the health of the public. In the wake of the development of the basic law and other related laws, Japan has introduced a risk analysis approach (described above) to the national food safety control programme work. The Food Safety Basic Law assigns responsibility for risk assessment, and the Food Sanitation Law and other related laws identify who are responsible for risk management. The risk assessment is in practice conducted by the Food Safety Commission established under the Food Safety Basic Law.

CLIMATE CHANGE AND FOOD SAFETY

The earth's climate is changing, and this may influence the safety of food harvested from marine and freshwater environments. There are two main areas that have the potential for change: microbial pathogens, and harmful algal blooms.

Microbial pathogens

Climate change is expected to accelerate the water cycle with increased precipitation in the tropics and at high altitudes, drier conditions in subtropics and increased frequencies of extreme droughts and floods. Events such as floods are likely to disrupt sanitary infrastructure around fish harvesting and aquaculture sites, affecting fish safety. The presence of *Salmonella* in rivers and the marine environment has been related to torrential rains and storm-generated flows, and the pathogen could thus reach aquaculture sites or contaminate fish in coastal waters. Outbreaks of illness caused by *Vibrio parahaemolyticus* in shellfish in Chile have been related to the arrival of warm equatorial water during El Niño events.

Harmful algal blooms

Harmful algal blooms are a completely natural phenomenon that have occurred throughout recorded history in all parts of the globe. Whereas wild fish stocks are free to swim away from problem areas, caged fish and shellfish are trapped and, thus, can suffer mortalities and/or become toxic. Of greatest concern to human society are algal species that produce potent neurotoxins that can find their way through shellfish and fish to consumers, where they cause a variety of gastrointestinal and neurological illnesses. Worldwide, almost 2 000 cases of food poisoning from consumption of contaminated fish or shellfish are reported each year. Some 15 percent of these cases prove fatal. In the past three decades, harmful algal blooms seem to have become more frequent, more intense and more widespread, in part ascribed to climate changes. The seafood industry (capture and farmed) must monitor for an increasing number of harmful algal species in the water column and for an increasing number of algal toxins in seafood products. Global climate change is adding a new level of uncertainty to many seafood safety monitoring programmes.

IMPACT ON DEVELOPING COUNTRIES

While efforts in the major markets are focusing on a regulatory framework to ensure the safety of their consumers, several development agencies and donors have been exploring ways and means, both financial and technical, to assist developing exporting countries build the necessary national and regional capacity to meet these international safety and quality standards. Proper assessment of the extent of assistance needed is key in decision-making. Therefore, costing the impact of substandard products, from

both a quality and safety perspective, is of interest not only to producers, processors, quality control authorities and consumers, but also to governments, donors, public health authorities and development agencies. In addition to the economic losses incurred because of fish spoilage, product rejections, detention and recalls, and the resulting adverse publicity to an industry and even to a country, fish-borne illnesses cost vast amounts to the community because of adverse health effects, loss of productivity and medical expenses.

Fish and seafood are crucial income earners for many developing countries. Trade liberalization has reduced tariff barriers, which should have a positive impact on developing countries' access to developed country markets. However, it is increasingly clear that the main barrier to increased exports is no longer import tariffs but the difficulties developing countries have in meeting import market quality-related and safety-related requirements.

Developing countries have pointed to the challenge presented by national and regional safety and quality control regimes that vary from one jurisdiction to the next. This multitude of approaches imposes significant costs on exporters in countries where there is limited capacity to develop comprehensive safety and quality management systems and infrastructures, let alone several different systems to meet diverse import market requirements. Although progress has been made in terms of harmonization, in particular via the WTO and the CAC, it has been slow and more work is required.

The concerns expressed by developing countries in relation to public regulation in importing countries are mirrored in their concerns related to private standards for food safety. The costs of compliance (including the duplication of effort required to complete various levels of documentation), the need to respond to a multiplicity of different standards, the increasing specificity of those standards, and the lack of harmonization among them are major concerns for developing countries. Much effort has gone into meeting European Union and other importer requirements in many

Box 16

An Indian success story

Small farmers with holdings of less than 2 ha account for 90 percent of shrimp aquaculture in India. The outbreak of white spot disease seriously affected the shrimp aquaculture industry in India in the mid-1990s and the related losses in 1995–96 were estimated at about US$120 million. Subsequently, the problem of antibiotic residues affected market access for shrimp in India. To address this, better management practices (BMPs) using a cluster-based approach were started in one state. In 2001, this approach was demonstrated in 10 ponds covering 7 ha and producing 4 tonnes of shrimp. The BMPs contributed to improved production and reduced diseases without the use of antibiotics. This initiative slowly expanded to 108 ponds covering 58 ha in 2003, and, by 2007–08, it had expanded to 5 states in India covering an area of 6 826 ha. The BMPs included documentation of inputs, which facilitated implementation of traceability in this sector of small farmers. The goal is to organize 75 000 farmers into 1 500 societies by the end of 2012.

Source: Umesh, N.R., Mohan, A.B.C., Ravibabu, G., Padiyar, P.A., Phillips, M.J., Mohan, C.V. and Vishnu Bhat, B. 2010. Shrimp farmers in India: empowering small-scale farmers through a cluster-based approach. *In* S.S. De Silva and F.B. Davy, eds. *Success stories in Asian aquaculture*, pp. 44–66. Dordrecht, Netherlands, Springer Science+Business Media B.V.

developing countries. Consequently, more than 100 countries, most of them developing countries, are approved exporters of fish products to the European Union because they have food safety management systems equivalent to those of the European Union. However, for other developing countries, poor public infrastructure challenges their abilities to meet either public or private overseas standards.

Furthermore, many developing countries have been unable to access the growing market for higher value-added products. Instead, their processing activities have been limited to less sophisticated types of processing (filleting and canning). Private-sector companies appear unwilling to invest in more sophisticated production equipment in developing countries if their activities are not supported by the public infrastructure. Companies can and do relocate processing to developing countries – including to take advantage of lower labour costs – where they have confidence in the local administrative systems (including safety and quality management regimes). Integrated supply chains mean closer collaboration with import markets. This could also mean opportunities for transfers of technology and expertise to developing countries.

Some countries have introduced state-mediated certification procedures to certify their safety and environmental credentials, in particular in their aquaculture industries. This can be seen as a proactive strategy to respond to safety and quality demands from import markets by promoting themselves as suppliers of safe and high quality fish and seafood, e.g. Thai Quality Shrimp.

Organizing fishers and fish farmers in developing countries, for example, by encouraging farmers/fishers associations or clusters (Box 16), enables them to respond collectively to the requirements of both public and private standards, and ensures that they are able to take advantage of available technical assistance.

For developing countries to take advantage of the opportunities presented by private standards, they must first be able to meet the requirements of mandatory regulatory requirements in importing countries. Compliance with mandatory requirements is a prerequisite to any private-sector certification, but the reverse is not true. For example, certification to a private standard scheme will not allow access to the European Union market if the exporting country itself (and its competent authority) has not been given the green light to export to the European Union.

Hence, there is a need for continued technical assistance and dissemination of relevant information to developing nations to help them meet the ever-increasing and more complex challenges posed by international markets.

Marine protected areas: a tool for the ecosystem approach to fisheries

INTRODUCTION

As people have become more aware of their impact on the environment and the possible consequences thereof not only on their current well-being but also for future generations, the recognition of the need for protection balanced with sustainable use of the world's natural resources has increased dramatically. There have been calls for integrated and holistic natural-resource management approaches, focusing on ecosystems rather than only on specific species or ecosystem components. In response, various international fora have advocated adoption of more holistic approaches such as the ecosystem approach, and the use of tools such as marine protected areas (MPAs) and MPA networks. One of the primary fora that first brought MPAs to the forefront of discussions on global marine conservation was the Johannesburg Summit of 2002 – the World Summit on Sustainable Development. Its Plan of Implementation requests that nations promote the conservation and management of important and vulnerable marine and coastal areas.

In fact, spatial management measures, including MPAs, or fishing closures as a management tool have a long history in fisheries (see Box 17). With the current move

Box 17

Marine protected areas, fisheries and the Code

In fisheries management, spatial management tools, including marine protected areas, are not new – they have been used for centuries. Protection of specified areas through bans on types of gear and fishing activities has long been part of the fisheries management toolbox and practised by communities employing traditional management arrangements around the world. The FAO Code of Conduct for Responsible Fisheries (the Code) mentions the use of spatial management measures, for example, in Article 6.8, which emphasizes the importance of protection and rehabilitation for all critical habitats, and particularly protection against human impacts such as pollution and degradation.[1] In an effort to promote its goal – sustainable fisheries – the Code addresses protected area measures in Article 7.6.9:

"States should take appropriate measures to minimize waste, discards, catch by lost or abandoned gear, catch of non-target species, both fish and non-fish species, and negative impacts on associated or dependent species, in particular endangered species. Where appropriate, such measures may include technical measures related to fish size, mesh size or gear, discards, closed seasons and areas and zones reserved for selected fisheries, particularly artisanal fisheries."

[1] FAO. 1995. *Code of Conduct for Responsible Fisheries*. Rome. 41 pp.

in fisheries management towards the ecosystem approach to fisheries (EAF) and similar methods, their use may become even more prevalent.

Hence, a convergence of interests has come about as fisheries managers emphasize healthy ecosystems as a requirement for sustainable fisheries. Conservation groups have also become increasingly aware of the necessity to include human needs and interests in designing and implementing MPAs. However, there remains confusion regarding the establishment of MPAs with varying objectives, as well as the general role of MPAs meeting multiple objectives within fisheries management systems. Views on how and when to use MPAs and what they can achieve differ significantly among diverse political, social and professional groups, and also among individuals.

Considering this confusion and the attention given to MPAs, the FAO Fisheries and Aquaculture Department has developed guidelines on MPAs and fisheries[15] (hereafter, the Guidelines) with a view to clarifying the bioecological and socio economic constraints and effects of MPAs in the context of fisheries. The Guidelines address the interface between fisheries management and biodiversity conservation, and they provide guidance on implementing MPAs with multiple objectives where one of the primary objectives is related to fisheries management. They draw on experiences from around the world and make use of a number of national case studies conducted in order to gather information on governance regimes of spatial management measures.

BACKGROUND

The diversity of marine protected areas

A stumbling block in many discussions on MPAs is the terminology; what is an MPA? The MPA concept is applied diversely around the world and with different names for similar policies. The many terms used for protected areas include, to name a few, fully protected marine areas, no-take zones, marine sanctuaries, ocean sanctuaries, marine parks, fishery closed areas, fisheries refugia and locally managed marine areas (while other protected areas in aquatic environments also include freshwater protected areas [Box 18]). Moreover, the same term may have different meanings in different countries or locations, e.g. a "reserve" in one country may prohibit fishing, while a "reserve" in another country may allow certain forms of non-destructive fishing. Box 19 gives some examples of national-level definitions extracted from the FAO MPA case studies.[16]

The Guidelines do not propose a single definition for MPAs but adopt a broad characterization in order to facilitate discussion of the various aspects considered important; hence, any marine geographical area that is afforded greater protection than the surrounding waters for biodiversity conservation or fisheries management purposes is considered an MPA. It is recognized that this characterization includes very large areas, such as exclusive economic zones (EEZs) at the extreme, but the term MPA is usually understood to apply to areas specifically designated to protect a particular ecosystem, ecosystem component or some other attribute (e.g. historical site).

An MPA network refers to two or more MPAs that complement one another. Ecological networks are formed when the natural connections among and within sites enhance ecological functions. However, besides ecological networks, social and institutional networks are also possible and can contribute to enhancing the administration and management of MPAs through communication, sharing of results and coordination among institutions.

Effects of MPAs: lessons learned

The effects of MPAs and MPA networks on fishery resources, ecosystems and people depend on a variety of factors, including their location, size, number, the nature of the protection afforded and the movement of the fish species (at all life stages) across MPA boundaries. It is also important to consider activities occurring outside the MPA itself.

Box 18

Freshwater protected areas

Freshwater protected areas (FPAs) have been a common fishery management practice in many areas to address the threats facing freshwater species and habitats. Following habitat rehabilitation and stock enhancement, the use of FPAs is the third-most common intervention to protect freshwater fish populations.[1] Closed fishing seasons and areas, prevention of fishing on spawning grounds, wild and scenic river designations, and native fish conservation areas can all be considered FPAs to one extent or another. However, the usual impression of an FPA involves a designated geographic area that is permanently protected, i.e. closed to fishing and other anthropogenic impacts. While less well known than marine protected areas, FPAs are subject to the same issues relating to diversity of terminology and meaning.

[1] Cowx, I.G. 2002. Analysis of threats to freshwater fish conservation: past and present challenges. *In* M.J. Collares-Pereira, I.G. Cowx and M.M. Coelho, eds. *Conservation of freshwater fish: options for the future*, pp. 201–220. Oxford, UK, Blackwell Science.

Experience shows that, when designed and managed appropriately, MPAs will probably provide benefits for fishery resources inside the enclosure in terms of abundance (in number and biomass) and average individual size of populations. There may also be some benefits to the fishery in the areas close to the MPA as a result of spillover, but fewer studies are available on this effect. In general, conservation benefits are likely to be greater for more sedentary species, and fisheries benefits should be greater for species with intermediate mobility. Marine protected areas can also play an important role in the protection of habitats and critical life stages, and in reducing bycatch.

Box 19

Different national definitions of marine protected area

In Brazil, there are two main categories of protected areas: areas under total protection (no-take zones); and areas for sustainable use. The main difference between them relates to permission to extract natural resources and to live inside their boundaries – forbidden in the former and allowed in the latter. Within these two categories, there are different types of no-take and sustainable-use protected areas, each of them with specific objectives.

In the Philippines, a wide range of terms is used for marine protected areas (MPAs). Their use may vary depending on the legislation, designating authority and type and quality of the resources and the intent. However, in practice, a standardized terminology is emerging among policy-makers with MPAs being defined as "any specific marine area which has been reserved by law or other effective means and is governed by specific rules or guidelines to manage activities and protect part or the entire enclosed coastal and marine environment".

In Senegal, the concept of MPAs continues to be the subject of numerous discussions with regard to their objectives, origin, legal status, relevant institutions, and design and implementation approaches. In the legal framework, the role of MPAs has been defined as "protection, on a scientific basis, for current and future generations, of important natural and cultural resources and ecosystems representative of the marine environment". In practice, MPAs in Senegal have two main characteristics. First, the purpose of MPAs is to contribute to the conservation of marine and coastal biodiversity. Second, an area of particular interest can be designated according to bioecological, territorial or socio-economic considerations and given special management measures for improving conservation, while taking the livelihoods of the resource users into account.

Palau characterizes MPAs through two distinct categories: management and use. The first type follows the six levels of the management guidelines of the International Union for Conservation of Nature, while the second includes traditional, local and national uses of protected areas. Many MPAs in Palau encompass a range of levels or types of management.

Sources: Sanders, J.S., Gréboval, D. and Hjort, A., comps. 2011. *Marine protected areas: country case studies on policy, governance and institutional issues.* FAO Fisheries and Aquaculture Technical Paper No. 556/1. Rome, FAO. 118 pp.
Sanders, J.S., Gréboval, D. and Hjort, A., comps. (forthcoming). *Marine protected areas: country case studies on policy, governance and institutional issues.* FAO Fisheries and Aquaculture Technical Paper No. 556/2. Rome, FAO.

However, the use of an MPA or MPA network as the only management tool to control or reduce fish mortality or to sustain fish populations is likely to result in overall lower fisheries yield potential and higher costs of fishing. The MPA should be combined with other management measures that control fishing effort outside the protected area, or fishing effort will probably be displaced with potentially negative consequences. Hence, MPAs must be an integral part of overall fisheries management plans and should not be viewed as a stand-alone fisheries management tool unless they are the only viable option, such as in situations where the capacity to implement other forms of management is lacking.

Because MPAs decrease the fishing area, they are likely to mean – at least in the short term – lower yields for fishers who cannot fish efficiently elsewhere. Benefits from changes in the fishery resource thanks to MPAs may be realized only in the longer term. Coastal communities adjacent to MPAs, especially those with a high economic dependence on the fishery, could thus face a disproportionate impact as a result of aggregate reduction in fishing revenue.

Appropriately designed and managed MPA networks can have several benefits compared with single MPAs. A network may be more flexible with regard to the distribution of social and economic costs and benefits among various stakeholders (fishers), while still achieving fisheries management and biodiversity conservation objectives. A network is also more likely to provide higher resilience to catastrophic events and other changes in the environment, such as climate change.

One tool in the fisheries management toolbox

When wishing to use an MPA or MPA network as a tool within fisheries management or the conservation of marine biodiversity, it is important to keep in mind the full set of management tools available. Indeed, MPAs and MPA networks are only one tool among many other fisheries management and biodiversity conservation measures. As such, they have strengths and weaknesses and should not be considered a “magic bullet”. They are effective for management when planned and implemented under the right circumstances and through appropriate processes in combination with other tools. Both the opportunities and the limitations they represent should be respected and their suitability assessed in relation to what is to be achieved in a specific situation. Therefore, defining the overall fishery management and biodiversity conservation objectives is a fundamental element of the planning process, and the MPA or MPA network, if found to be suitable for these objectives, must be embedded within broader policy and spatial management frameworks. Considering that MPAs will have multisectoral effects (whether they have been designed with multiple objectives or not), they should be designed within a framework such as the EAF or integrated coastal zone management, with appropriate cross-sectoral coordination and collaboration established at all levels (national, regional and local) to ensure that externalities are capitalized on or mitigated.

PLANNING AND IMPLEMENTATION: LESSONS LEARNED

When an MPA has been appropriately designed, its success will depend on how well it is managed and whether it is implemented effectively. Issues related to governance span two main dimensions: the existence of an enabling environment through legal, institutional and policy frameworks; and the management structure and institutional requirements at the level of the individual MPA or MPA network (including with regard to the process by which it is planned and designated).

Decisions on design and on the governance regime should be made in accordance with the objectives of the MPA. The setting of objectives is a critical first step that goes beyond the MPA concept itself. Only when the fisheries management objectives, including biodiversity conservation, have been defined can it be decided whether an MPA or an MPA network is the best tool for achieving them. If this is found to be the case, the goals and objectives of the individual MPA or MPA network can be decided. Most MPAs have biological, socio-economic and governance goals and objectives.

Governance perspectives

Whether designated primarily for biodiversity conservation or for fisheries management – or with multiple objectives – MPAs require supporting legal, institutional and policy frameworks, as well as long-term political commitment, in order to be successful. They are tools for achieving defined objectives and are most effective when embedded within broader management frameworks such as an EAF or a spatial management framework that requires intersectoral coordination. Moreover, good governance, including stakeholder participation, is key to successful and equitable management outcomes.

The institutional arrangements for spatial management measures vary considerably among countries. They include both the broad framework of rules and processes that guide societal and economic activities and the entities that operate within this framework (government agencies, institutions, committees, councils, organizations, etc.). The legal framework of laws and regulations defines the rights, responsibilities, options and restrictions applicable to all affected stakeholders, and provides the basis for protection and enforcement of rights and responsibilities. Box 20 provides examples of national institutional structures for MPAs.

Box 20

Examples of national institutional MPA arrangements

In Senegal, marine protected areas (MPAs) have been covered by forestry legislation and have fallen under the responsibility of the National Parks Department of the Ministry of Environment. However, MPAs created more recently have instead been designated by presidential decree or by provincial governor approval. In 2009, a new Department for Community Areas was created within the Ministry of Maritime Affairs. This department will have responsibility for community-managed MPAs. There have also been attempts to establish procedures to facilitate coordination of MPA designation between the two ministries. Moreover, in 2010, a marine interministerial committee was created to, among other things, facilitate the development of an ecosystem approach to marine management.

In the Philippines, the authority to establish and manage MPAs is held by three jurisdictions: the Department of Environment and Natural Resources; the Bureau of Fisheries and Aquatic Resources of the Department of Agriculture, and the local government unit. Both of the national government agencies have responsibilities for protecting marine environments, although their mandates may sometimes overlap. The Local Government Code of 1991 contains several important measures that enhance the administrative abilities of local government units, including political autonomy and the ability to generate and mobilize economic resources through taxes and fees. Local government units possess broad powers to control fishing activities in coastal waters and are able to set conditions for marine resource use by local ordinance, including the establishment of MPAs. Local government units do not require the approval of the national government agencies to establish MPAs.

Sources: Sanders, J.S., Gréboval, D. and Hjort, A., comps. 2011. *Marine protected areas: country case studies on policy, governance and institutional issues.* FAO Fisheries and Aquaculture Technical Paper No. 556/1. Rome, FAO. 118 pp.
Eisma-Osorio, R.L., Amolo, R.C., Maypa, A.P., White, A.T. and Christie, P. 2009. Scaling-up local government initiatives towards ecosystem-based fisheries management in Southeast Cebu Island, the Philippines. *Coastal Management,* 37(3–4): 291–307.

The international workshop "Exploring the Role of MPAs in Reconciling Fisheries Management with Conservation" (29–31 March 2011, Bergen, Norway) focused on the need for and role of MPAs with multiple objectives. It also discussed the need for institutional arrangements, noting that a coordinating interministerial or intersectoral institution may be needed at the national level to reconcile objectives (fisheries management and biodiversity conservation, as well as those related to the interests of, for example, local communities and the tourism sector). Such a body would need to make strategic trade-offs between sectors and balance different power structures. Moreover, vertical links in the decision-making processes from the local level to the national policy level are required, with appropriate representation of different interests at each level.

The types of management arrangement and governance regime under which an MPA can be planned and implemented depend on the conditions provided by the overall legal, institutional and policy framework. While centralized, state-controlled, command-and-control systems are still common, there has been a trend towards increasingly decentralized fisheries management in recent decades. Various forms of comanagement governance systems are applied in many parts of the world, based on partnerships between governments and resource users with shared responsibility and authority for fisheries management. These governance systems are often combined with rights-based approaches to fisheries management.

Stakeholder involvement in planning and implementation is crucial for the success, in particular, of coastal MPAs. The socio-economic impacts of an MPA can be positive and negative, direct and indirect, affecting sectors and stakeholders adjacent to and beyond the MPA site. Marine protected areas have distributional effects, often very significant ones, and different stakeholder groups are affected in different ways. People, individually and as a group, should be made to feel that they have been part of the decision-making process and have been able to participate in and influence it. Without their involvement, it will be difficult to obtain support and compliance.

Setting objectives

Within the context of the defined overall fisheries management and/or biodiversity conservation objectives, specific goals and objectives should be set for the individual MPA or MPA network. There should be both longer-term visionary goals and operational objectives. The goals and objectives should be easy to understand and widely communicated. Because MPAs will have multisectoral effects, multiple goals should be considered even where the original initiative to designate an MPA has emerged from one particular concern. For example, when setting up an MPA for biodiversity conservation, its harmonization with relevant fisheries policies and legislation, and its potential contribution to sustainable fisheries should also be explored. If the effects on fisheries are internalized in the planning and design process, instead of being dealt with as an externality, the outcomes are likely to be more useful. Setting clear goals and objectives helps ensure more-effective management and facilitates the monitoring of progress. When the specific MPA objectives are set, decisions on the site, scale and other design aspects of the MPA should follow. These decisions should be goal- and objective-driven.

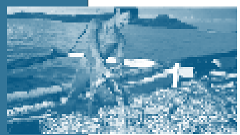
The Bergen MPA workshop also emphasized the need to establish clearly defined goals and objectives. The need for baseline assessments that will allow for monitoring was also raised. The design and management of an MPA should be flexible and adaptive, allowing for adjustment of management if monitoring shows that the objectives are not being reached.

As in all management planning processes, early involvement of stakeholders in the MPA planning process is important. This means that stakeholders should be involved in identifying the issues that the MPA is expected to address and resolve and in the setting of MPA goals and objectives. The diversity and type of information brought to bear on decisions depends on who has the right to participate in decision-making processes. Consequently, participatory planning arrangements generally increase the amount of information integrated into MPA planning and implementation. When taking a holistic and integrated approach to MPA planning, the process of identifying and agreeing on pertinent issues is likely to be complex. With a broad range of stakeholders and views on what aspects are important, prioritization becomes a critical element of the process. Several methods and approaches can help both in the identification of issues as well as when defining goals and objectives (Box 21).

THE WAY FORWARD

The current trend towards greater emphasis on MPAs as a fisheries management and biodiversity conservation tool will continue both within the framework of the EAF and in the context of the international commitments made on conservation and sustainable development. In attempting to maximize the contribution of this spatial management measure to achieving healthy marine ecosystems and sustainable fisheries, and meeting broader societal objectives – including poverty reduction and food security – there are both opportunities and challenges.

The Bergen MPA workshop recognized the increasing reconciliation between the fisheries management and biodiversity goals. However, it also found that further institutional arrangements, such as legal frameworks, stakeholder/community participation and coordination among high-level agencies, have to be secured in order to enhance reconciliation and realize both perspectives.



Current trends in the devolution of power to local levels of government and communities, for example, through fisheries and ecosystem comanagement arrangements, support stakeholder involvement in MPA planning and implementation. This is an important development that MPAs can both benefit from and contribute to –

Box 21

Tools for analysis and prioritization

Various analytical frameworks can assist in the decision-making and prioritization process when selecting what issues a marine protected area should address and what the goals and objectives should be:

- A hierarchical or problem tree is often used as part of participatory planning and helps define root causes by clustering identified problems and issues.
- Analysis is used to determine the economic efficiency of various options from among which decision-makers must choose. Put simply, future costs and benefits are estimated for each option and compared.
- Assessments are essentially used to determine whether the probability of a particular hazard or threat, combined with the magnitude of its possible impact or cost, is considered acceptable or not when compared with some standard or benchmark.
- Impact reviews examine who will benefit or suffer, the total costs and benefits (as in cost–benefit analysis), and the temporal and spatial distribution thereof.

Source: De Young, C., Charles, A. and Hjort, A. 2008. *Human dimensions of the ecosystem approach to fisheries: an overview of context, concepts, tools and methods*. FAO Fisheries Technical Paper No. 489. Rome, FAO. 152 pp.

experiences from MPA management can inform policy on decentralization and shared responsibilities.

Marine protected areas, which need to be integrated into wider fisheries and biodiversity management frameworks, imply a long-term management undertaking, and both political commitment and sustainable resourcing are required. Adequate support in terms of human and other resources must be planned from the outset and could include multiple funding sources. Considerable time, effort and perseverance will be required to make MPAs and MPA networks fulfil their potential.

Demand and supply of aquafeed and feed ingredients for farmed fish and crustaceans: trends and future prospects

INTRODUCTION

The global population is increasing and, in order to maintain at least the current level of per-capita consumption of aquatic foods, the world will require an additional 23 million tonnes thereof by 2020. This additional supply will have to come from aquaculture. Meeting the future demand for food from aquaculture will largely depend on the availability of quality feeds in the requisite quantities. Although the discussion on the availability and use of aquafeed ingredients often focuses on fishmeal and fish-oil resources (including low-value fish[17]), considering the past trends and current predictions, the sustainability of the aquaculture sector will probably be closely linked with the sustained supply of terrestrial animal and plant proteins, oils and carbohydrates for aquafeeds. Apart from ensuring the sustained availability of feed ingredients to meet the growing demand of aquaculture, several other important areas and issues also require attention. FAO Fisheries and Aquaculture Technical Paper No. 564[18] analyses the demand and supply of feed ingredients in aquaculture, raises several issues and questions, and provides recommendations on how to meet the challenge of increasing aquaculture production. These aspects are reviewed below.

AQUACULTURE GROWTH AND AQUAFEED

In 2008, global aquaculture production totalled 68.8 million tonnes, made up of 52.9 million tonnes of aquatic animals and 15.9 million tonnes of aquatic plants.[19] The volume of farm-produced aquatic animals represented 46.7 percent of the global food fish supply in that year. Considering the increasing global population and recognizing that no additional supply from marine capture fisheries will only be obtained if overexploited stocks are brought back to their full potential, it has been estimated that, to maintain the current level of per-capita consumption, by 2030 the world will require at least another 23 million tonnes of aquatic animal food – which aquaculture will have to provide.

Although aquatic plants and molluscs are produced under natural conditions without any additional feed, other aquatic animals requires some form of feed. Filter-feeding finfishes (e.g. silver carp and bighead carp) receive their food, primarily in the form of phytoplankton and zooplankton, in the pond or other waterbody through natural productivity and/or through fertilization. These fishes do not require any other forms of feeding, thus aquafeeds are not used for their production.

Aquafeeds (Box 22) are generally used for feeding omnivorous fishes (e.g. tilapia, catfish, common carp, and milkfish), carnivorous fishes (e.g. salmon, trout, eel, seabass, seabream and tuna) and crustacean species (marine and brackish-water shrimps, freshwater prawns, crabs and lobsters).

According to FAO estimates, in 2008, about 31.7 million tonnes (46.1 percent of total global aquaculture production including aquatic plants) of fish and crustaceans were feed-dependent, either as farm-made aquafeeds[20] or as industrially manufactured compound aquafeeds.[21] In 2008, fed aquaculture contributed to 81.2 percent of global farmed fish and crustacean production of 38.8 million tonnes and 60.0 percent of global farmed aquatic animal production.

While more than 200 species of fish and crustaceans are currently believed to be fed on externally supplied feeds, just 8 species or species groups account for 62.2 percent of the total feed used. These are: grass carp, common carp, Nile tilapia, Indian major carps (catla and rohu), whiteleg shrimp, crucian carp, Atlantic salmon, and pangasiid catfishes. More than 67.7 percent of farmed fed fish production is contributed by freshwater fishes, including carps and other cyprinids, tilapias, catfishes and miscellaneous freshwater fishes.

AQUAFEED PRODUCTION AND USE

Some fed-aquaculture farming systems use low-cost earthen ponds in semi-intensive production systems for the mass production of freshwater omnivorous fishes destined for local domestic consumption. However, they also range up to the use of more-intensive pond-, cage- or tank-based systems for the production of freshwater, diadromous and marine carnivorous fishes and crustaceans for export or high-end domestic markets.

The choice of feeding method depends upon a variety of factors (which may vary from country to country and from farmer to farmer) and objectives (local/home consumption or cash crop/export). Important factors include the market value of the cultured species, the financial resources of the farmer and the local availability of appropriate fertilizers and feeds.

The FAO technical paper highlighted here deals mainly with fish and crustaceans fed through exogenous feed, particularly industrially produced aquafeed (as comprehensive information on other feed types is generally lacking). Compound aquafeeds are used for the production of both lower-value (in marketing terms) food-fish species, such as non-filter-feeding carps, tilapias, catfishes and milkfish, as well as higher-value species, such as marine finfishes, salmonids, marine shrimps, freshwater eels, snakeheads and crustaceans.

Globally, 708 million tonnes of industrial compound animal feeds were produced in 2008, of which 29.2 million tonnes were aquafeeds (4.1 percent of all animal feeds). As animal production has increased, so has global industrial compound animal feed production – almost fourfold from 7.6 million tonnes in 1995 to 29.2 million tonnes

Box 22

Fed fish and non-fed fish

Fish fed with aquafeeds during culture practice are referred to as “fed fish”, while fish that do not receive any feed are generally referred to as “non-fed fish”. Aquaculture practices that produce fed fish are called “fed aquaculture”,[1] as opposed to “non-fed aquaculture”.

As the same species of fish may be cultured as fed fish or non-fed fish in different production systems, it is difficult to obtain precise production data and information on the use of feed for several aquaculture species, especially some omnivorous species (e.g. common carp, and Indian major carps) and herbivorous species (e.g. grass carp). For example, in many aquaculture production systems, grass carp are fed exclusively on plant materials and/or grasses, while in other systems this species is produced through externally supplied farm-made or commercial aquafeed. This situation makes it difficult to produce accurate estimates of feed use for many such species.

[1] Fed aquaculture is aquaculture production that utilizes, or has the potential to utilize, aquafeeds of any type; in contrast to the farming of filter-feeding invertebrates and aquatic plants, which relies exclusively on natural productivity.

in 2008, at an average rate of 11 percent per year. Production is expected to grow to 51.0 million tonnes by 2015 and to 71.0 million tonnes by 2020.

By volume, industrial compound aquafeeds used by major species and species groups are estimated to have been as follows in 2008: fed carps (9.1 million tonnes, 31.3 percent of the total), marine shrimps (17.3 percent), tilapias (13.5 percent), catfishes (10.1 percent), marine fishes (8.3 percent), salmons (7.0 percent), freshwater crustaceans (4.5 percent), trouts (3.0 percent), milkfish (2.0 percent), eels (1.4 percent), and miscellaneous freshwater fishes (1.6 percent).

While there is no comprehensive information available on the global production of farm-made aquafeeds,[22] the estimate is that it was between 18.7 million and 30.7 million tonnes in 2006. Farm-made aquafeeds play an important role in the production of low-value freshwater fish species. More than 97 percent of carp feeds used by Indian farmers are farm-made aquafeeds (7.5 million tonnes in 2006/07), and they are the mainstay of feed inputs for low-value freshwater fishes in many other Asian and sub-Saharan countries.

Although, again, accurate information is lacking, it has been estimated that the total use of low-value fish (i.e. as raw ingredients not reduced into fishmeal) in aquaculture was between 5.6 million and 8.8 million tonnes in 2006 and that, in 2008, Chinese aquaculture alone used 6–8 million tonnes of low-value fish, including marine fish, freshwater fish, and live food fish.

FEED INGREDIENT PRODUCTION AND AVAILABILITY

Feed ingredients used for the production of aquafeeds are broadly categorized into three types depending upon their origin: animal nutrient sources (including both aquatic and terrestrial animals); plant nutrient sources; and microbial nutrient sources.

Aquatic animal protein meals and lipids

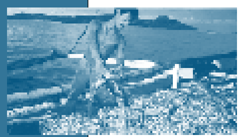
The major aquatic animal protein meals and lipids used in aquafeeds include: fish/shellfish meals and oils; fish/shellfish by-product meals and oils; and zooplankton meals and oils.

Fishmeal and fish oil derived from wild-harvested whole fish and shellfish including bycatch currently constitute the major aquatic protein and lipid sources available for animal feed. World reduction fisheries (marine capture fishery products converted to fishmeal) were 18.2 million tonnes in 1976. This total rose progressively to 30.2 million tonnes in 1994 but then declined steadily to 17.9 million tonnes in 2009.[23] As a result, fishmeal and fish-oil production exhibited similar trends. Global fishmeal production increased from 5.00 million tonnes in 1976 to 7.48 million tonnes in 1994 and then decreased steadily thereafter to 5.74 million tonnes in 2009. Similarly, global fish-oil production rose gradually from 1.02 million tonnes in 1976 to 1.50 million tonnes in 1994 (with the exception of production peaks of 1.67 million and 1.64 million tonnes recorded in 1986 and 1989, respectively) but then fell back steadily to 1.07 million tonnes in 2009. Hence, analysis of the data for the last 15 years (1994–2009) indicates that global fishmeal and fish-oil production from marine capture fisheries have been decreasing at annual average rates of 1.7 and 2.6 percent, respectively.

The amount of captured fish destined for non-food uses increased from 20.6 million tonnes in 1976 to 34.2 million tonnes in 1994 (a proportionate increase from 31.5 to 37.1 percent of total catch). Since 1995, this amount has been decreasing both in absolute terms and as a proportion of total catch. In 1995, 31.3 million tonnes of global fish and shellfish landings were destined for non-food uses (33.9 percent of total catch), and, out of this total, 27.2 million tonnes (29.5 percent of total catch) were reduced into fishmeal and fish oil. In 2009, the corresponding figure was 22.8 million tonnes (25.7 percent of total). Out of this total, 17.9 million tonnes (20.2 percent of total catch) were reduced into fishmeal and fish oil. The amount of captured fish destined for non-food uses will probably decrease further in the near future.

In recent years, increasing volumes of fishmeal and fish oil have originated from fisheries by-products (capture fisheries and aquaculture). An estimated 6 million tonnes of trimmings and rejects from food fish are currently used for fishmeal and fish-oil production. The International Fishmeal and Fish Oil Organisation estimates that about 25 percent of fishmeal production (1.23 million tonnes in 2008) comes from fisheries by-products. This amount will grow as its processing becomes increasingly viable. Accurate information on the proportion of by-product fishmeal and fish oil produced from aquaculture processing waste is not available, but it is probable that a significant volume of farmed fish wastes is contributed.

Although some marine zooplanktons have potential for use as feed ingredients for aquaculture, commercial operations only exist for Antarctic krill (*Euphausia superba*), with total landings of 118 124 tonnes in 2007. Although krill meal and krill oil are available, information concerning their total global production and market availability is currently unavailable. While there are large biomasses of other zooplankton species in the oceans, it is probably unlikely that zooplankton meals will become a major protein ingredient in feed for farmed fish in the on-growing phase. It is more reasonable to expect that relatively minor amounts of zooplankton meal may be used as a bioactive ingredient, or attractant, in aquafeed or in feed for fish larvae.



Terrestrial animal protein meals and fats

The major terrestrial animal protein meals and lipids commonly used in aquafeeds are: (i) meat by-product meals and fats; (ii) poultry by-product meal, hydrolysed feather meal and poultry oil; and (iii) blood meals. Although accurate information is not available, it has been estimated that the global combined production levels of rendered animal protein meals and fats in 2008 were about 13.0 million and 10.2 million tonnes, respectively.

Plant nutrient sources

The major plant dietary nutrient sources used in aquafeeds include: cereals, including by-product meals and oils; oilseed meals and oils; and pulses and protein concentrate meals.

Total global cereal production was 2 489 million tonnes in 2009, growing at an annual average rate of 2.2 percent since 1995, with maize totalling 817.1 million tonnes (32.8 percent of the total), followed by wheat, rice paddy, and barley.

In 2009, oilseed production was 415 million tonnes, with soybean being the largest and fastest-growing oilseed crop and accounting for slightly more than 50 percent (210.9 million tonnes) of this total. About 151.6 million tonnes of soybean meal were produced in 2008/09, and other major oilseed protein meals were: rapeseed (30.8 million tonnes), cottonseed (14.4 million tonnes), sunflower seed (12.6 million tonnes), palm kernel (6.2 million tonnes), groundnut/peanut (6.0 million tonnes), and copra/coconut (1.9 million tonnes).

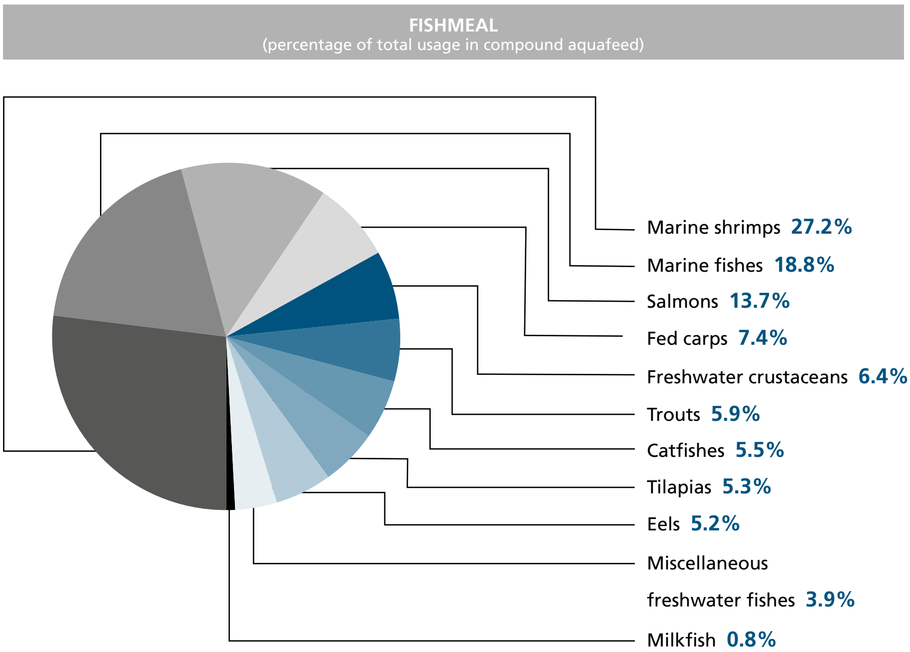
Among the pulses, protein concentrate meals from peas and lupins are commercially available for use within compounded animal feeds, including aquaculture feeds. The total global production figures for dry peas and lupins were 10.5 million and 0.93 million tonnes, respectively, in 2009.

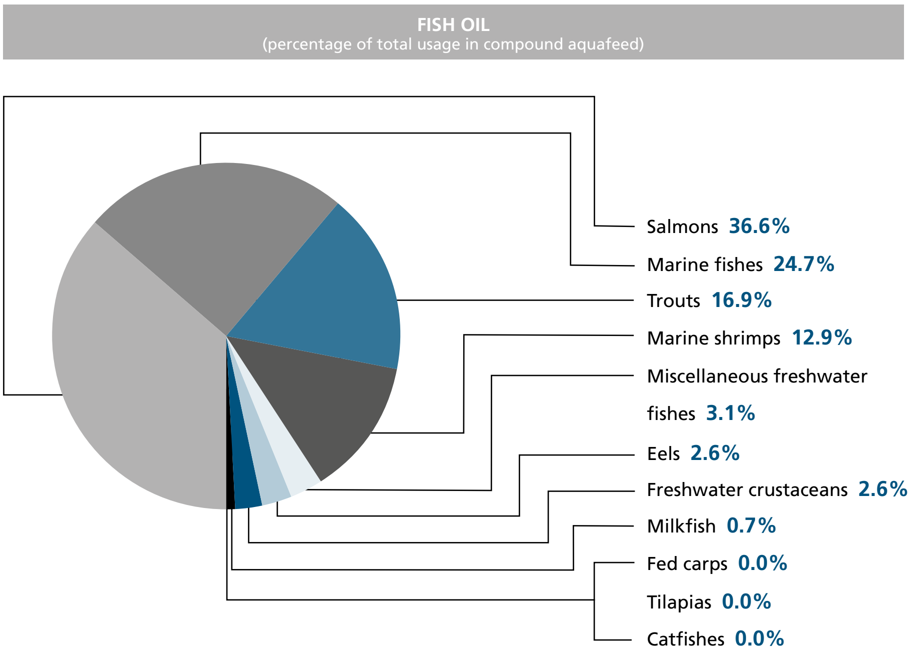
Microbial ingredient sources

Microbial-derived feed ingredient sources for aquafeed include algae, yeasts, fungi, bacteria and/or mixed bacterial/microbial single-cell protein sources. The only such sources available in commercial quantities globally are yeast-derived products, including brewer's yeast and extracted fermented yeast products, but with limited information concerning their total global production and availability. Given the relatively low cost of some of these single-cell proteins, they are probably most relevant as a major protein ingredient in fish feed or may at least partially replace fishmeal in feeds for some fish species. Although microbial and algal species are considered innovative protein sources for aquafeeds, production costs will be an issue with some of them.

Figure 42

Global consumption of fishmeal and fish oil by major aquaculture species groups in 2008





Source: Adapted from Tacon, A.G.J., Hasan, M.R. and Metian, M. 2011. *Demand and supply of feed ingredients for farmed fish and crustaceans: trends and prospects.* FAO Fisheries and Aquaculture Technical Paper No. 564. Rome, FAO. 87 pp.

CURRENT FEED INGREDIENT USAGE AND CONSTRAINTS

Fishmeals and fish oils

Within the animal husbandry subsectors, aquaculture is the largest user of fishmeal and fish oil. Their use in aquafeeds is more prevalent for higher-trophic-level finfishes and crustaceans (with fishmeal inclusion levels of 17–65 percent and those for fish

oil of 3–25 percent). However, low-trophic-level finfish species/species groups (carps, tilapias, catfishes, milkfish, etc.) are also fed fishmeal and fish oil in varying amounts in their diets. The fishmeal use for these diets varies between 2 and 10 percent, with the exception of those for tilapias and catfishes in a few countries where up to 25 percent fishmeal use has been reported.

There is a wide variation in fishmeal and fish-oil usage between major species and species groups, with shrimps, marine fishes and salmons being the largest combined users thereof (Figure 42).

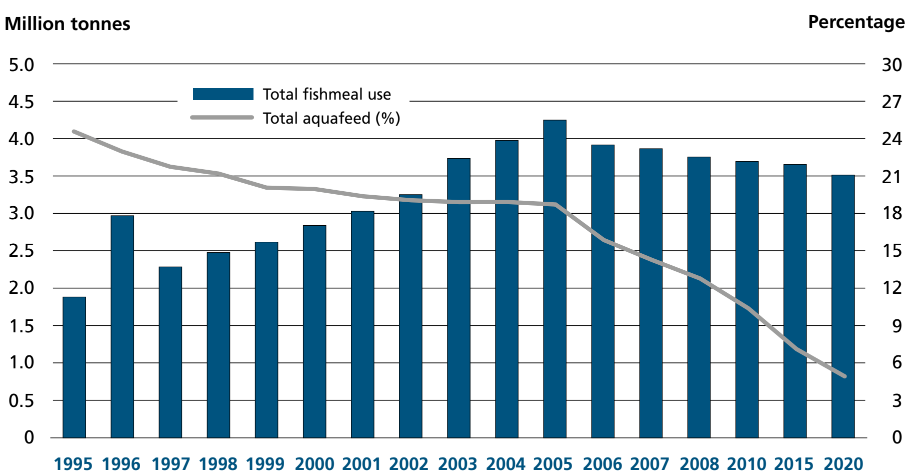
Although global fishmeal and fish-oil supplies have fluctuated between 4.57 million and 7.48 million tonnes for the last 33 years and have now stabilized at about 5.0–6.0 million tonnes per year, the amounts of fishmeal and fish oil used in aquafeeds have grown – rising between 1995 and 2008 from 1.87 million tonnes to 3.73 million tonnes and from 0.46 million tonnes to 0.78 million tonnes, respectively. This has been possible at the expense of the land-animal sector, particularly the pig and poultry sector, which is continuously reducing its use of fishmeal. In 1988, 80 percent of world fishmeal production was used in feed for pigs and poultry while only 10 percent went to aquaculture feed. In 2008, aquaculture used 60.8 percent of world fishmeal production and 73.8 percent of fish-oil production.

As mentioned above, low-value fish are also increasingly used as aquafeeds for carnivorous species, particularly in Asia. Increased use of fishmeal, fish oil and low-value fish in aquaculture in the last 10–12 years has primarily been attributed to the worldwide increase in the production of carnivorous species, particularly marine crustaceans, marine finfish, salmonids and other diadromous fishes.[24]

Although the aquaculture sector remains the largest user of fishmeal in the world, fishmeal use in aquafeeds has gradually fallen since 2006. Aquaculture consumed about 4.23 million tonnes (18.7 percent of total aquafeeds by weight) of fishmeal in 2005, but this figure was down to 3.72 million tonnes in 2008 (12.8 percent). It has been predicted that, even with increasing aquaculture production globally, the use of fishmeal for aquafeeds will decrease further to 3.63 million tonnes by 2015 (7.1 percent of total aquafeeds for that year) and to 3.49 million tonnes by 2020 (4.9 percent) (Figure 43). Among the reasons for this reduction are: decreased supplies of industrially

Figure 43

Actual and predicted reduction in fishmeal use relative to the global production of compound aquafeed



Source: Adapted from Tacon, A.G.J., Hasan, M.R. and Metian, M. 2011. *Demand and supply of feed ingredients for farmed fish and crustaceans: trends and prospects.* FAO Fisheries and Aquaculture Technical Paper No. 564. Rome, FAO. 87 pp.

caught fish as a result of tighter quotas; additional controls on unregulated fishing; and increased use of more cost-effective dietary fishmeal replacers.

In recent decades, because of an increased awareness of the likelihood of a scarcity of fishmeal, research institutions and the aquaculture feed industry have conducted numerous studies to try to reduce dependence on fishmeal. These studies have provided more detailed knowledge on the digestive processes and nutritional requirements of many farmed species and on how to process raw materials to make them more suitable for use in feed. Since 1995, this increased knowledge has led to an impressive reduction in the average inclusion of fishmeal in compound feeds for major groups of farmed species as well as improved feed conversion ratios (FCRs), reducing the amount of waste from the industry.

In the last 13 years for which data are available (1995–2008), fishmeal inclusion in major fish diets declined considerably (Table 16). The FAO technical paper projects that, in the next 10–12 years, fishmeal inclusion in the diets of carnivorous fish and crustacean species will be further reduced by 10–22 percent, and by 2–5 percent for omnivorous fishes.

Moreover, with improved feed efficiency and management, the FCRs for many aquaculture species dependent on industrially manufactured compound aquafeeds are projected to decline. For example, the FCR for fed carps is expected to fall from 1.8 in 2008 to 1.6 in 2020, that for catfishes to decline from 1.5 to 1.3, and that for milkfish to drop from 2.0 to 1.6. If these materialize, coupled with lower fishmeal inclusion in the diets for the above species and species groups, the amount of fishmeal used will decrease by about 6 percent in spite of the projected increases of 143 and 168 percent in estimated total aquafeed and fed aquaculture production, respectively.

Although it is projected that fish-oil inclusion in the diets for different carnivorous fish and crustacean species will also be reduced by 0.5–7.0 percent over the next ten years, the use of fish oil by the aquaculture sector will probably increase in the long run, albeit slowly. The total amount used will increase by more than 16 percent, from 782 000 tonnes (2.7 percent of total aquafeeds by weight) in 2008 to 845 000 tonnes by 2015 (1.7 percent) and to 908 000 tonnes by 2020 (1.3 percent). The reasons for this increase are the rapidly growing marine finfish and crustacean aquaculture sector and the absence of cost-effective alternative sources of dietary lipids rich in long-chain highly unsaturated fatty acids (HUFAs), including eicosapentaenoic acid (20:5n-3) and

Table 16

Reduction in fishmeal inclusion in compound aquafeed of different fish species and species groups

Species/species group	Fishmeal inclusion in compound aquafeed		
	1995	2008	2020*
	(Percentage)		
Fed carp	10	3	1
Tilapias	10	5	1
Catfishes	5	7	2
Milkfish	15	5	2
Miscellaneous freshwater fishes	55	30	8
Salmons	45	25	12
Trouts	40	25	12
Eels	65	48	30
Marine fishes	50	29	12
Marine shrimps	28	20	8
Freshwater crustaceans	25	18	8

* Projected.
Source: Adapted from Tacon, A.G.J., Hasan, M.R. and Metian, M. 2011. *Demand and supply of feed ingredients for farmed fish and crustaceans: trends and prospects.* FAO Fisheries and Aquaculture Technical Paper No. 564. Rome, FAO. 87 pp.

docosahexaenoic acid (22:6n-3). There is also a growing demand for fish oil for direct use as human supplements and pharmaceutical medicines.

Alternatives to fish oil are being used in greater amounts. Key alternative lipids include vegetable oils (e.g. linseed, soybean, canola and palm) – those with a high omega-3 content are preferred – and poultry oil. The use of oil from farmed fish offal is also a potential source of omega-3 for farmed fish.

Although a reduction in the dietary inclusion level of fish oil in aquafeed would not have any deleterious effect on the health of the farmed target species, there may be reduced health benefits from the final fish products because of lower HUFAs, including eicosapentaenoic and docosahexaenoic acid levels. Therefore, intensive research is required in order to find alternatives to fish oil. Research is aiming to produce long-chain omega-3 fatty acids from hydrocarbons by yeast fermentation, through extraction from algal sources and/or through genetic modification of plants.

In order to keep pace with fed aquaculture production, global aquafeed production will continue to grow, and it is expected to reach 71.0 million tonnes by 2020. The FAO technical paper highlighted here also indicates that, although the availability of fishmeal and probably fish oil over the next ten years may not be a major constraining factor, other feed ingredient and input supplies will need to expand at a similar rate if this growth is to be sustained, and these inputs will have to come from other sources (e.g. soybean, corn, and rendered animal by-products).

Terrestrial animal meals and oils

In non-European countries, the use of terrestrial animal protein meals and oils within compound aquafeeds is increasing for both high- and low-trophic-level species and species groups (e.g. salmons, trouts, marine finfishes, marine shrimps, catfishes, tilapias, carps and mullets), although the type and level vary depending upon species and species group. The inclusion level is generally: 2–30 percent for poultry by-product meal; 5–20 percent for hydrolysed feather meal; 1–10 percent for blood meal; 2–30 percent for meat meal; 5–30 percent for meat and bone meal; and 1–15 percent

Table 17
Feed ingredient usage for major aquaculture species and species groups

Feed ingredients	Inclusion level in compound aquafeed (Percentage)
Plant protein meal	
Soybean meal	3–60
Wheat gluten meal	2–13
Corn gluten meal	2–40
Rapeseed/canola meal	2–40
Cottonseed meal	1–25
Groundnut/peanut meal	≈ 30
Mustard oil cake	≈ 10
Lupin kernel meal	5–30
Sunflower seed meal	5–9
Canola protein concentrate	10–15
Broad bean meal	5–8
Field pea meal	3–10
Plant oil	
Rapeseed/canola oil	5–15
Soybean oil	1–10

Source: Adapted from Tacon, A.G.J., Hasan, M.R. and Metian, M. 2011. *Demand and supply of feed ingredients for farmed fish and crustaceans: trends and prospects.* FAO Fisheries and Aquaculture Technical Paper No. 564. Rome, FAO. 87 pp.

for poultry oil. Despite the apparent increasing trend, it is estimated that the total usage of terrestrial animal by-product meals and oils within compound aquafeeds ranges between 0.15 million and 0.30 million tonnes, or less than 1 percent of total global compound aquafeed feed production. Thus, there is considerable room for expansion.

Plant protein meals and oils

Plant protein meals commonly used in aquafeed include soybean meal, wheat gluten meal, corn gluten meal, rapeseed/canola meal, cottonseed meal, sunflower seed meal, groundnut/peanut meal, mustard oil cake, lupin kernel meal, and broad bean meal; and plant oils include rapeseed/canola oil, soybean oil, and palm oil. Plant proteins represent the major dietary protein source used within feeds for lower-trophic-level fish species and the second major source of dietary protein and lipids (after fishmeal and fish oil) for marine shrimps and European high-trophic-level fish species (e.g. salmons, trouts, marine fishes, and eels). Other species and species groups that use substantial amounts of plant protein meals and oils include milkfish, mullets, freshwater prawns, cachama and freshwater crayfishes. The inclusion levels of plant protein meals and oils vary widely depending upon species and species group (Table 17).

Soybean meal is the most common source of plant protein used in compound aquafeeds and the most prominent protein ingredient substitute for fishmeal in aquaculture feeds, with feeds for herbivorous and omnivorous fish species and crustaceans usually containing 15–45 percent soybean meal, with a mean of 25 percent in 2008. In global terms, and based on a total compound aquafeed production of 29.3 million tonnes in 2008, it is estimated that the aquaculture feed sector consumes about 6.8 million tonnes of soybean meal (23.2 percent of total compound aquafeeds by weight). Other plant proteins that are being increasingly used include corn products (e.g. corn gluten meal), pulses (e.g. lupins and peas), oilseed meals (rapeseed meal, cottonseed and sunflower), and protein from other cereal products (e.g. wheat, rice and barley).

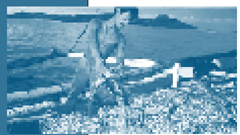
Currently, plant protein and/or oil choice and selection are based upon a combination of local market availability and cost, as well as their nutritional profile (including antinutrient content and level). With the continued rise in the fishmeal price, plant protein concentrates (soybean protein concentrate, canola protein concentrate, pea protein concentrate and corn/wheat gluten meals) will gain increasing prominence over regular plant protein meals within aquafeeds for high-trophic-level cultured species and crustaceans. For example, the demand for soybean protein concentrates within aquafeeds is projected to exceed 2.8 million tonnes by 2020.

CONCLUSION

The discussion on the availability and use of aquafeed ingredients often focuses on fishmeal and fish-oil resources (including low-value fish). However, considering past trends and current predictions, the sustainability of the aquaculture sector is more likely to be closely linked to the sustained supply of terrestrial animal and plant proteins, oils and carbohydrate sources for aquafeeds. Therefore, the aquaculture sector should strive to ensure sustainable supplies of terrestrial and plant feed ingredients.

Apart from ensuring the sustained availability of feed ingredients (including fishmeal and fish oil) to meet the growing demand of aquaculture, the other important areas that need to be explored are:

- developing coping strategies and farmers' resilience to increases and fluctuations in raw material prices;
- addressing the supply of feed and feed ingredients to poor producers, particularly in sub-Saharan countries where farmers and small-scale feed manufacturers need assured access to feed and feed ingredients;
- ensuring national quality standards for feed raw materials, feed additives and feeds;
- facilitating the safe and appropriate use, and reliable quality, of aquafeeds produced by small-scale feed manufacturers;
- improving on-farm feeding and feed management practices and the transfer of associated technology at farmer level;



- improving feed formulation and production (e.g. farm-made feed, and semi-commercial feed) at the local level;
- improving the capacity, production technology and associated support services of small-scale feed manufacturers in Asia and sub-Saharan Africa.

ISSUES TO BE ADDRESSED

Continued emphasis on alternatives to fishmeal and fish oil

Aquaculturists should continue to search for alternative sources of affordable and high-quality plant- and animal-based feed ingredients to replace fishmeal in aquafeeds. Much research has already been carried out on plant feed ingredients to enhance their nutritional quality, with significant successes. Therefore, it is imperative that equal priority be given to improving the quality of terrestrial products and/or by-products, considering that the total volume of terrestrial animal by-product meals and oils used within compound aquafeeds is less than 1 percent of the total volume of global compound aquafeed feed production.

Continued research on fish-oil substitutes will be a priority. The objective should be to maintain the quality of farmed target species in respect of HUFAs in the final products, as it is projected that the overall total usage of fish oil in aquaculture will increase although the fish-oil inclusion level in various carnivorous fish and crustacean species is expected to decrease.

Reducing country dependence upon imported feed ingredient sources

Feed manufactures in developing countries should be encouraged to reduce their use of imported feed ingredients and fertilizers by fostering, through outreach and training opportunities, the use of locally available feed ingredients.

Special focus on small-scale farmers and aquafeed producers

There is an urgent need to assist and train those resource-poor farmers who use farm-made and semi-commercial aquafeeds, not only to minimize the use of unnecessary feed additives and chemicals (including antibiotics) but also to improve feed management techniques. Farm-made feeds need to be improved through research and development (R&D) programmes focusing on factors such as ingredient quality, seasonal variability, marketing and storage, and improvements in processing technology. These R&D efforts need to be supported by improved extension services. There is also a need for support services that can help improve and build the production processes and capacity of small-scale aquafeed producers.

Minimizing the environmental impact of feeds and feeding regimes

An effort to minimize the environmental impact of feeds and feeding regimes may include: (i) the use of highly digestible feed ingredients; (ii) the selection of a mix of species so that one or more species can benefit from the nutrient waste streams produced by other species inhabiting the same aquatic milieu; and (iii) culture of fish under closed biofloc-based zero-water exchange culture conditions.[25]

Diversification of feed and fertilizer resources

There should be a greater effort to promote the diversified utilization of feed and fertilizer resources through research, extension and information on the nutritional requirements of farmed species and the nutrient content of the available feed materials.

Global guidelines on ecolabelling and certification in capture fisheries and aquaculture

INTRODUCTION

Ecolabelling and certification schemes are increasingly being used in the global trade and marketing of fish and fish products. The visible signs of these schemes are labels that those adhering to the schemes may place on the products they offer for sale. The label guarantees that the product originates in capture fisheries and/or aquaculture enterprises that are sustainably managed and/or that adhere to criteria reflecting social and cultural values deemed important by the scheme's originators. In this manner, consumers can promote sustainable resource use through the purchase of labelled products; or, as this is sometimes expressed, ecolabels and certification schemes use market forces to incentivize more responsible use of physical and human resources.

Large-scale retailers and food services now drive the demand for certification of both aquaculture and capture fishery products in relation to food safety and quality, sustainability and social criteria.[26] The presence of an ecolabel, for example, helps retailers and brand owners meet the growing consumer demand for products originating from sustainably managed fisheries. In some markets, retailers look for niche products that are certified as organic fish, or for a degree of social responsibility in the production systems and practices.

In addition, ecolabels and certification help retailers by ensuring that the products delivered by a range of certified international suppliers, at times operating in different continents, are standardized in terms of sustainability, food safety, quality and traceability depending on the specific ecolabel or certification.

FAO Members first discussed ecolabels in 1996 at a meeting of the FAO Committee on Fisheries (COFI). Several Members expressed concerns at the emergence of ecolabelling schemes and especially that they could become non-tariff barriers to trade. In 1996, there was no consensus that FAO should become substantively involved.

However, in keeping with its mandate to monitor developments in world fisheries and aquaculture, FAO continued to assemble information on ecolabelling and certification schemes. In particular, information was assembled regarding:

- environmental sustainability;
- food safety and quality;
- human well-being;
- animal welfare.

Drawing on this information, FAO organized a first Technical Consultation in 1998 to investigate the possibility of developing guidelines on the ecolabelling of fish and fish products. The Technical Consultation[27] did not reach agreement on FAO's role in developing such guidelines, except to concur that any future guidelines should be consistent with the FAO Code of Conduct for Responsible Fisheries (the Code), and that FAO should not be directly involved in the actual implementation of any ecolabelling scheme. However, in the absence of global initiatives to standardize the development of the use of ecolabelling and certification schemes in fisheries and aquaculture, and with a growing number of such schemes, COFI agreed in 2003 that FAO should develop guidelines on ecolabelling.[28]

Since then, FAO has developed the following guidelines:

- Guidelines for the Ecolabelling of Fish and Fishery Products from Marine Capture Fisheries (Marine Guidelines), 2005/2009;[29]
- Guidelines for the Ecolabelling of Fish and Fishery Products from Inland Capture Fisheries (Inland Guidelines), 2011;[30]
- Guidelines on Aquaculture Certification (Aquaculture Guidelines), 2011.[31]

The FAO COFI Sub-Committee on Fish Trade has recently discussed a draft "Framework for assessment of ecolabelling schemes in inland and marine capture fisheries" (February 2012).

THE MARINE GUIDELINES

The Marine Guidelines were adopted in 2005. Focusing on issues related to the sustainable use of fisheries resources, they are of a voluntary nature and applicable to ecolabelling schemes designed to certify and promote labels for products from well-managed marine capture fisheries. They contain principles, general considerations, terms and definitions, minimum substantive requirements and criteria, and procedural and institutional aspects.

The principles require that any ecolabelling scheme should be consistent with relevant international law and agreements, including the 1982 United Nations Convention on the Law of the Sea, the Code, and WTO rules and mechanisms. They also require that ecolabelling schemes should be market-driven, transparent and non-discriminatory, including by recognizing the special conditions applying to developing countries.

The Marine Guidelines were revised in 2009 to take into account a request by COFI that FAO should review and provide more guidance on the general criteria in relation to "stock under consideration" and to serious impacts of the fishery on the ecosystem. The revised guidelines call for the minimum substantive requirements and criteria of ecolabelling schemes to include the following elements:

- The fishery is conducted under a management system that is based on good practice, including the collection of adequate data on the current state and trends of the stocks and based on the best scientific evidence.
- The stock under consideration is not overfished.
- The adverse impacts of the fishery on the ecosystem are properly assessed and effectively addressed.

Furthermore, the procedural and institutional aspects of ecolabelling schemes should encompass:

- the setting of certification standards;
- the accreditation of independent certifying bodies;
- the certification that a fishery and the chain of custody of its products are in conformity with the required standards and procedures.

In the light of improved capacity to farm marine fish and the need for increased food from aquatic ecosystems, stock enhancement and the use of introduced species may become more common management interventions also in the marine environment. The Marine Stewardship Council has recently addressed species introductions and enhancements in its ecolabelling scheme[32] and developed policy on when such fisheries would be within the scope thereof. Currently, without revising the Marine Guidelines, it would not be possible to assess whether the scheme operated by the Marine Stewardship Council would comply with the Marine Guidelines when assessing enhanced marine fisheries or those marine fisheries based on introduced species. Because FAO is developing benchmarks to assess whether private schemes comply with these guidelines, consideration may need to be given to revising the Marine Guidelines in order to address explicitly the issues of stock enhancement and species introductions.

THE INLAND GUIDELINES

When adopting the Marine Guidelines in 2005, the Twenty-sixth Session of COFI requested that FAO also prepare guidelines on the ecolabelling of fish and fishery products from inland capture fisheries (Inland Guidelines). The Inland Guidelines are similar to the Marine Guidelines in all aspects except for some differences in scope.

During development of the Inland Guidelines, it became clear that the use of enhancement is common in inland fisheries. However, there are several different forms of enhancement, and some may be more appropriately considered forms of aquaculture than forms of capture fisheries. It became evident that not all enhanced fisheries could be subject to the Inland Guidelines.

Enhanced fisheries are those "that are supported by activities aimed at supplementing or sustaining the recruitment of one or more aquatic organisms and raising the total production, or the production of selected elements of a fishery, beyond a level which is sustainable by natural processes. Enhancement may entail stocking with material originating from aquaculture installations, translocations from the wild and habitat modification."[33]

Enhancement practices range from minor interventions either in the flow of water and/or in a flora or fauna, to highly controlled aquaculture systems that release animals into semi-natural environments. Thus, there is a need to define carefully the scope of fisheries eligible for an ecolabel in regard to, *inter alia*, the relationship between the type of enhancement activities or production system and the intent of management with respect to the "stock under consideration".

FAO declared that the characteristics and management of the "stock under consideration" would decide whether or not the enhanced fisheries would fall within the scope of the Inland Guidelines. It also declared that to be within the scope of the Inland Guidelines, enhanced fisheries must meet the following criteria:

- The species are native to the fishery's geographic area or were introduced far back in time and have subsequently become established as part of the "natural" ecosystem.
- There are natural reproductive components of the "stock under consideration".
- The growth during the post-release phase is based upon food supply from the natural environment, and the production system operates without supplemental feeding.

Enhanced fisheries may comprise naturally reproductive components and components maintained by stocking. The overall enhanced fishery should be managed in such a way that the naturally reproductive components are managed in accordance with the provisions of Article 7 of the Code. The management system of enhanced fisheries should permit a verification that proves that stocking material originating from aquaculture facilities meets the provisions of Article 9 of the Code.

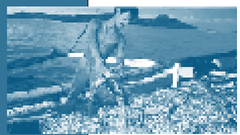
FAO concluded that culture-based fisheries, specifically, those supported solely by stocking (i.e. with no associated management intent to sustain the natural reproduction components and capacity of the "stock under consideration"), would not fall within the scope of the Inland Guidelines.

In 2010, an FAO Expert Consultation[34] recommended that guidelines on culture-based fisheries could be developed either by using the aquaculture certification guidelines or by establishing a separate set of certification guidelines for this category of enhanced fisheries.

Another difference between the Marine Guidelines and Inland Guidelines regarding scope is the approach to ecolabelling fisheries based on introduced species. There are circumstances where countries with depauperate inland fauna or modified aquatic ecosystems may wish to introduce new species to increase production and value from these systems. Although international guidelines and risk assessment exist to help make responsible introductions, FAO felt that the application of guidelines, risk assessment and subsequent monitoring and enforcement were not sufficiently established to ensure adequate protection of inland aquatic ecosystems. Therefore, inland fisheries based on new species introductions would fall outside the scope of the Inland Guidelines and only inland fisheries on species introduced "historically" would be eligible for ecolabelling.

THE AQUACULTURE GUIDELINES

In 2011, the Twenty-ninth Session of COFI approved the FAO Technical Guidelines on Aquaculture Certification (Aquaculture Guidelines). While endorsing the guidelines, COFI recognized the existing standards and guidelines set by international organizations such as the World Organisation for Animal Health for aquatic animal health and welfare, the Codex Alimentarius Commission for food safety, and the International Labour Organization for socio-economic aspects. However, in the absence of a precise international reference framework for the implementation of some of the specific minimum criteria contained in the Aquaculture Guidelines, COFI recognized the importance of developing appropriate standards in order to ensure that aquaculture certification systems do not become unnecessary barriers to trade. It noted the necessity for the certification systems to remain consistent with and to comply with the provisions contained in the SPS Agreement and the TBT Agreement of the WTO. In addition, COFI also recommended that FAO develop an evaluation framework to assess the conformity of public and private certification schemes with the Aquaculture Guidelines.



The Aquaculture Guidelines provide guidance for the development, organization and implementation of credible aquaculture certification schemes. Minimum substantive criteria for developing aquaculture certification standards are provided for: (i) animal health and welfare; (ii) food safety; (iii) environmental integrity; and (iv) socio-economic aspects. The extent to which a certification scheme seeks to address the issues depends on its objectives. Therefore, the scheme should explicitly and transparently state its objectives. The Aquaculture Guidelines, which apply to voluntary certification schemes, are to be interpreted and applied in a manner consistent with their objectives, with national laws and regulations, and, where they exist, with international agreements.

The Aquaculture Guidelines make it clear that credible aquaculture certification schemes have three main components: standards, accreditation and certification. Therefore, the Aquaculture Guidelines cover: (i) standard-setting processes, which are needed to develop and review certification standards; (ii) accreditation systems, which are needed to provide formal recognition to a qualified body to carry out certification; and (iii) certification bodies, which are needed to verify compliance with certification standards.

The Aquaculture Guidelines recognize the fact that responsible development of aquaculture depends on social, economic and environmental sustainability, all of which have to be addressed. They also recognize that there is an extensive national and international legal framework in place for various aspects of aquaculture and its value chain, covering issues such as aquatic animal disease control, food safety and conservation of biodiversity.

The Aquaculture Guidelines recommend that developers of certification schemes should recognize that it is of vital importance that those who implement them are able both to measure the performance of aquaculture systems and practices and to assess conformity with certification standards.

EVALUATION FRAMEWORK

In 2009, COFI asked FAO to develop an evaluation framework to assess whether private or public ecolabelling schemes were in conformity with the Marine Guidelines. This followed earlier discussions in both COFI and the COFI Sub-Committee on Fish Trade regarding whether FAO could, or should, verify the correctness of claims being made by ecolabelling schemes that they complied with the Marine Guidelines. The advice from COFI to FAO was not to monitor the compliance actively, but instead to develop an evaluation framework for assessing whether private or public ecolabelling schemes for marine fisheries were in conformity with the Marine Guidelines. Such a framework would provide a transparent tool that could allow national ecolabelling schemes to be assessed against the Marine Guidelines. Schemes found to be consistent with the Marine Guidelines could then be considered equivalent to any other scheme that conforms to the Marine Guidelines.

In 2010, FAO convened an Expert Consultation that produced an evaluation framework. The evaluation framework identified indicators to permit an assessment of conformity with the Marine Guidelines and the Inland Guidelines. A total of 115 indicators were identified, 6 of which only apply to inland fisheries. At present, the assessment process enables the evaluator to determine whether a scheme conforms with the indicators identified in the evaluation framework, but only on a pass or fail basis. Complete conformity is possible only where all indicators have been included in the scheme being assessed. The evaluation framework was submitted to the COFI Sub-Committee on Fish Trade in February 2012 for discussion and subsequent forwarding to the Thirtieth Session of COFI (scheduled for July 2012).

Programmes to develop ecolabelling schemes have recently been initiated by a number of States, e.g. Iceland Responsible Fisheries (Iceland), and the California Sustainable Seafood Initiative and Alaska FAO-based Responsible Fisheries Management Certification (both in the United States of America). These initiatives have been partially driven by concerns about the costs associated with private ecolabelling schemes. However, public schemes may be perceived as self-serving. National administrations could be seen as certifying themselves, running the risk of being accused of a conflict of interest. Nonetheless, those national ecolabelling schemes assessed as being in compliance in the evaluation framework would significantly increase their legitimacy and the likelihood of receiving national and international recognition.

REMAINING ISSUES

Ecolabels and certification schemes arose in response to concerns for environmental sustainability and a perceived decline in the abundance of many of the world's major fish stocks. Owing to heightened consumer awareness and interest in environmental issues, it became clear that ecolabels and certification schemes could improve access to certain markets and provide a price premium for fish or fish products. It appears that ecolabelling and certification schemes have resulted in increased market share and price for some fisheries and suppliers. However, such a result is not guaranteed. For example, one study has shown that some certified coffee growers have become poorer in relation to conventional growers.[35] More studies are needed to know when a fishery should attempt to obtain an ecolabel or certification in order to increase profitability.

The efficacy of ecolabelling or certification as tools for improving the status of fisheries, i.e. changing poorly managed fisheries into well-managed ones, has not been well established. It is not clear how many of the concerned fisheries were poorly managed prior to the introduction of ecolabelling. Moreover, the question is still unanswered as to whether market forces in practice help to conserve aquatic resources. However, the onus is increasingly on suppliers to verify that their products meet certain standards, and certification provides this "burden of proof" (for further discussion of this issue, readers are referred to the publication on which this article is based[36]).

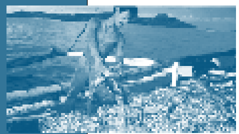
The OECD–FAO Agricultural Outlook: chapter on fish[37]

THE MODEL

Outlook models are very valuable for obtaining a good understanding on perspectives of developments in the sector they analyse. They are an important tool for providing organizations such as FAO and the Organisation for Economic Co-operation and Development (OECD), their Members and the international community with relevant information for developing strategic responses to emerging challenges. Internally, outlook studies can also help to highlight work priorities and to develop an overview of major challenges facing the organization.

Notwithstanding the importance of the fishery sector and its essential role in the livelihoods of millions of people around the world as a source of food, creator of employment, and contributor to economic growth and development, until 2010 FAO did not have a specific outlook model for fish on a short-term, medium-term or long-term perspective. Therefore, FAO decided to develop such a model to analyse the outlook of the fisheries and aquaculture sector in terms of future production potential, projected demand for fisheries products, consumption, prices and key factors that might influence future supply and demand.

It was considered important not to develop an isolated fish model but instead one integrated in the overall structure of an already existing and valid agricultural model, the OECD–FAO AGLINK–COSIMO Projection System, in view of the links and interactions of the fisheries and agriculture sectors. Fisheries, and in particular aquaculture, interact in several ways with agriculture. One evident example is in integrated farming, but more important is their impact on ecosystems, markets, products and prices, as well as on innovations and technology. Competition between the fishery sector and agriculture and livestock may arise over water and land resources, especially for irrigated agriculture, as well as in relation to the availability and relative efficiency of



the use of feeds between livestock and farmed fish. Capture fisheries play an important role also in terms of the production of fishmeal and fish oil, which are used as feed in aquaculture and in the diets of pigs, poultry, ruminants and companion animals. With the expansion of aquaculture, supplies of fishmeal have been largely directed to this sector. The growth of the aquaculture sector has also led to increasing demand for additional or substitutive sources of feed. Raw materials from agriculture and livestock, used traditionally to feed livestock, are being increasingly employed in the aquaculture sector. Continued growth in demand for livestock and fish has raised alarm over the sustainability of feed supplies, in particular for fishmeal, and the impacts of such growth on the environment.

The OECD–FAO AGLINK–COSIMO Projection System is one of the most comprehensive partial equilibrium models for the analysis of international agriculture and food markets. The model is used to generate medium-term projections on annual supply, demand and prices for selected agricultural commodities. Non-agricultural markets, including fish, are not modelled and are treated exogenously within the projection system. The overall design of the model focuses in particular on the potential influence of agriculture and trade policies on agricultural markets in the medium term. The model is one of the tools used in the generation of the baseline projections underlying the *OECD–FAO Agricultural Outlook* publication presenting projections and related market analysis for some 15 agricultural products over a ten-year horizon. The modelling framework was started by the OECD in the early 1990s through the development of its AGLINK model, an economic model of world agriculture with very detailed agriculture sector representation of OECD countries as well as of Argentina, Brazil, China and the Russian Federation. Since 2004, this modelling system has been greatly enhanced through the development by FAO of a similar agricultural model – COSIMO – representing the agriculture sectors of a large number of developing countries. For many countries, agriculture policies are specifically modelled within AGLINK–COSIMO. This makes the model a powerful tool for forward-looking analysis of domestic and trade policies through the comparison of scenarios of alternative policy settings against the benchmark of the baseline projections.[38]

In view of the importance and validity of the AGLINK–COSIMO modelling system, FAO, with the collaboration and agreement of the OECD and FAO Secretariats for AGLINK–COSIMO, decided to construct a satellite model on fish and fishery products, which has links to, but is not integrated into, the AGLINK–COSIMO model used for the agriculture projections. Being a satellite, it has been built following the same general principles used to build the AGLINK–COSIMO modelling system in order to facilitate its eventual integration. Since their creation, the AGLINK and then the COSIMO models have increased their size and coverage. The inclusion of the fishery component might represent an opportunity for the model to expand the coverage of food consumption, including an alternative and competitive source of food and protein, as well to expand the coverage of the oil and feed markets in order to have a better picture of the food and feed sectors.

The fish model is a dynamic, policy-specific, partial-equilibrium one. It contains 1 100 equations and covers the same 56 countries and regions as AGLINK–COSIMO with 42 of these countries endogenous as well as 5 continents and a world total. There are two types of supply functions: capture and aquaculture. Supply of capture fisheries can be exogenous or endogenous, but only affected by El Niño events, or endogenous but responding to price. For aquaculture, 99 percent of the total world is endogenous and responding to the price of output and the price of feed. Supply of fishmeal and fish oil consists of two components: from crushed whole fish (reduction) and from fish residues. Demand is for aggregate fisheries, but it is split according to three end uses: food, processed into fishmeal and fish oil, and other uses (kept exogenous). There are three links between the fishery and the agriculture markets: on the demand side through the substitution between fish and other animal products, through the amount of feed demanded by aquaculture, and through the interaction between fishmeal and fish oil and their respective oilseed substitutes.

In 2011, for the first time the OECD–FAO Agricultural Outlook publication (*OECD–FAO Agricultural Outlook 2011–2020*) included a separate chapter on fish, illustrating the main results of the fish model. The fish chapter was also incorporated in the 2012 edition, which covers projections for the period 2012–2021. Both chapters give a brief overview of the present situation of the fishery sector on production, trade and consumption. They then analyse the main results of the fish model, giving a plausible scenario in a ten-year horizon of what can be expected to happen under a certain set of assumptions, such as the macroeconomic environment, international trade rules and tariffs, frequency and effects of El Niño phenomena, absence of abnormal fish-related disease outbreaks, fishery quotas, longer-term productivity trends and the non-appearance of market shocks. These assumptions portray a specific macroeconomic and demographic environment that shapes the evolution of demand and supply for agricultural and fish products. Should any of these assumptions change, the resulting fish projections would be affected. Therefore, the chapters also illustrate the main issues and uncertainties that might affect the fishery sector and, as a consequence, the projections.

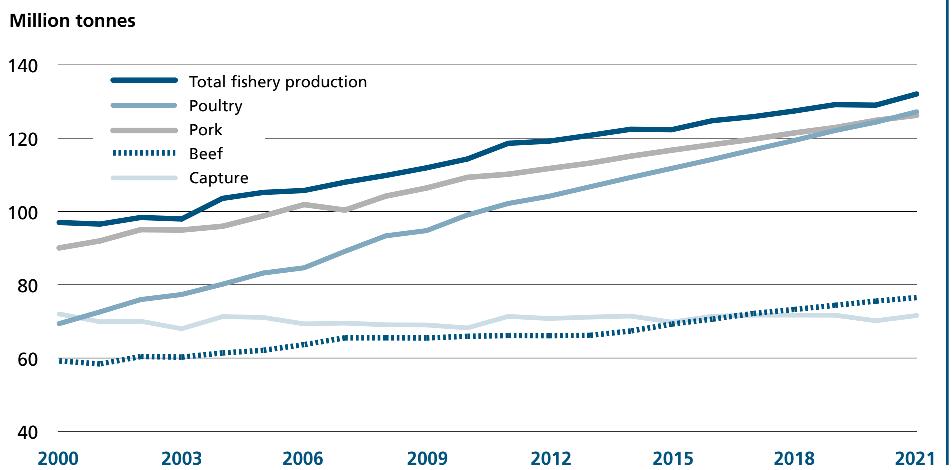
The main outcomes of the latest projections[39] included in the *OECD–FAO Agricultural Outlook 2012–2021* (publication date: June 2012) are summarized below.

PROJECTIONS 2012–2021

Stimulated by higher demand for fish, world fisheries and aquaculture production is projected to reach about 172 million tonnes in 2021, a growth of 15 percent above the average level for 2009–11. The increase should be mainly driven by aquaculture, which is projected to reach about 79 million tonnes, rising by 33 percent over the period 2012–2021 compared with the 3 percent growth of capture fisheries. However, a slowing in aquaculture growth is anticipated, from an average annual rate of 5.8 percent in the last decade to 2.4 percent during the period under review. This decline will be mainly caused by water constraints, limited availability of optimal production locations and the rising costs of fishmeal, fish oil and other feeds. Notwithstanding the slower growth rate, aquaculture will remain one of the fastest-growing animal food-producing sectors. Thanks to its contribution, total fisheries production (capture and aquaculture) will exceed that of beef, pork or poultry

Figure 44

Meat and fishery production, dressed weight or eviscerated basis



Notes: Total fishery production = capture + aquaculture. Beef and pork on a dressed-weight basis; poultry and fish on an eviscerated basis.
Sources: OECD and FAO Secretariats.

(Figure 44). Products derived from aquaculture will contribute to an increasing share of global fishery production, growing from 40 percent on average in 2009–2011 to 46 percent in 2021. Aquaculture production is expected to continue to expand on all continents, with variations across countries and regions in terms of the product range of species and product forms. Asian countries will continue to dominate world aquaculture production, with a share of 89 percent in 2021, with China alone representing 61 percent of total production.

The portion of capture fisheries used to produce fishmeal will be about 17 percent by 2021,[40] declining by 6 percent compared with the 2009–2011 average owing to the growing demand for fish for human consumption. In 2021, fishmeal production should be 15 percent higher compared with the 2009–2011 average,[41] but almost 87 percent of the increase will derive from improved use of fish waste, cuttings and trimmings. Growing income and urbanization will entail an increasing consumption of fish in fillets or prepared and preserved forms, thus creating more residual production to be used in fishmeal manufacturing. Fishmeal produced from fish waste should represent 43 percent of world fishmeal production in 2021 (Figure 45).

The fish sector is expected to enter into a decade of higher prices, but also higher production costs (Figure 46). The main drivers will be the underlying positive trend in demand, income and population growth, increasing meat prices, a generally weak US dollar and limited growth of capture fisheries production, as well as rising costs for some of the most important input factors such as energy, including crude oil and feed. In particular, as a consequence of slightly declining capture fisheries for reduction and a preference for fishmeal and fish oil in the production of certain animals, prices for fishmeal and fish oil are expected to grow by about 59 percent and 55 percent, respectively, in nominal terms during the projection period. Against the backdrop of stagnant supplies, increasing demand is expected to lead to an increase in the price ratio of fish to oilseed meal and oil, especially in assumed years of El Niño events. The impact of the coarse grain price on the price of aquaculture products will continue to be relatively modest, although it is expected to increase somewhat over the period 2012–2021. The price ratio of aquaculture compared with fishmeal will gradually stabilize over the period under review. Owing to the rising prices of fishmeal, fish oil and other feeds, the average price of farmed species should increase by slightly more

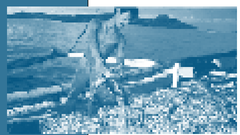
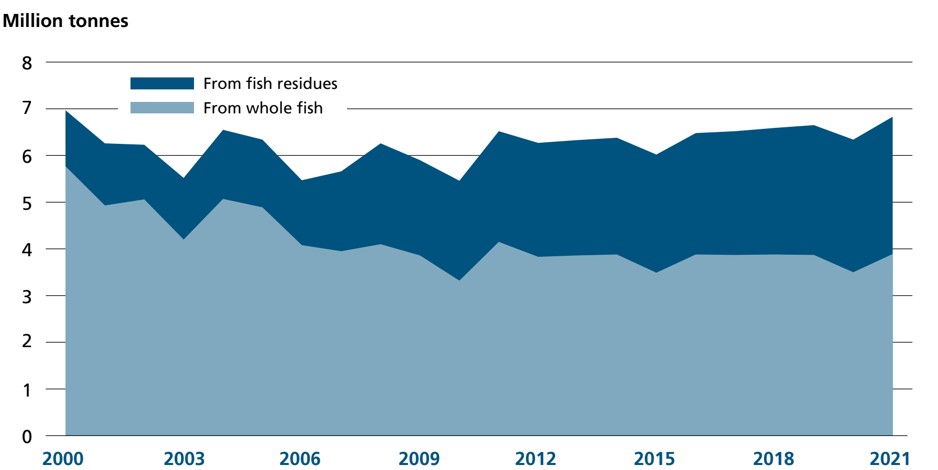


Figure 45

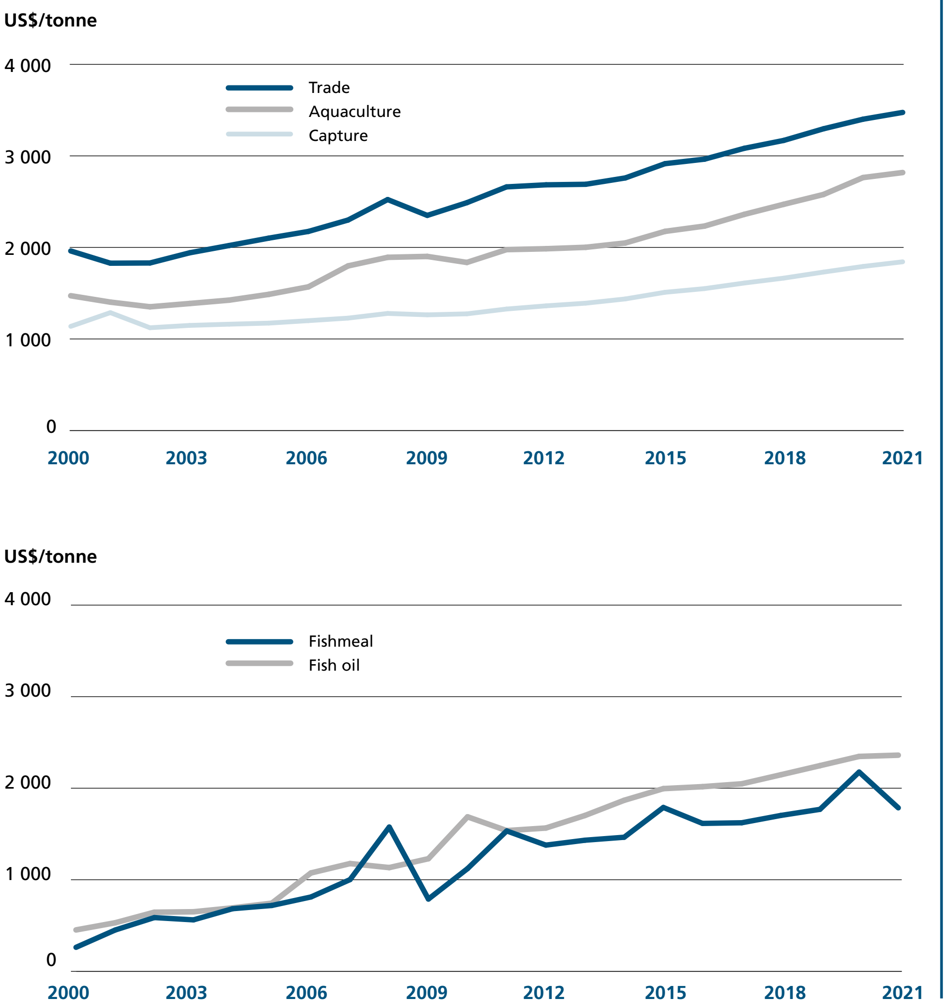
Fishmeal production in product weight



Sources: OECD and FAO Secretariats.

Figure 46

General growth in fish prices for high feed costs and strong demand, nominal terms



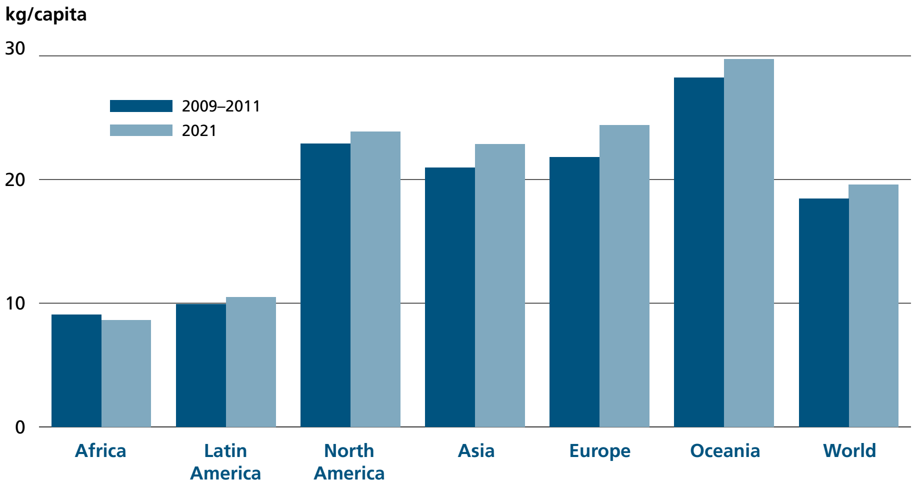
Sources: OECD and FAO Secretariats.

than that for capture fisheries (excluding fish for reduction), by 48 percent compared with 43 percent, in the next decade. Higher prices for substitutes, meat in particular, will stimulate demand for fish and fishery products for human consumption. This in turn, will increase fish prices, which will encourage more aquaculture production, in particular in developing countries, for export as well as for local and regional consumption.

World per-capita apparent fish consumption is expected to reach 19.6 kg in 2021, 16 percent higher than the average level for 2009–2011. The average annual growth rate will be lower in the second half of the projection period, when fish will start to become more expensive than red meats. Owing to high fish prices, fish consumption growth is projected to slow to 0.3 percent per year over the projection period, compared with 1.7 percent per year in the previous decade. Per capita fish consumption will increase in all continents (Figure 47), except in Africa (owing to population growing faster than supply), with Oceania showing the highest growth rate. Products derived from aquaculture will contribute to an increasing share of global fishery supply

Figure 47

Per capita fish consumption



Sources: OECD and FAO Secretariats.

for human consumption. By 2018, farmed fish is expected to exceed captured fish for human consumption for the first time, and its share is projected at 52 percent in 2021 (Figure 48).

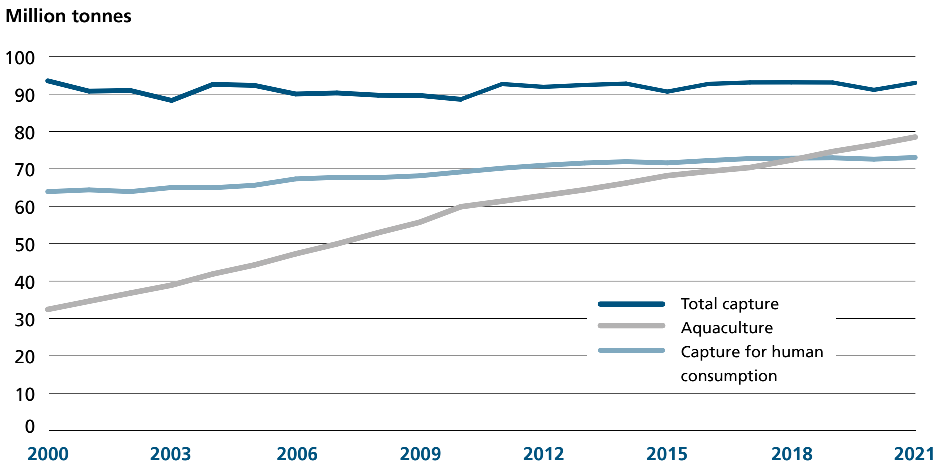
Fisheries supply chains will continue to be globalized, with a significant share of total fishery production being exported (39 percent, including intra-European Union trade). In quantity terms, world trade of fish for human consumption is expected to expand by 25 percent in the period 2012–2021. However, the annual growth rate of exports will decline from the 3.6 percent of the past decade to 1.9 percent over the next ten years. The share of developed countries in world fish imports for human consumption will fall from 59 percent to 56 percent in next decade. This will mainly be because of the growing imports by developing countries for domestic consumption as well as of unprocessed fish as raw material for their processing industries. Developing countries will continue to account for about 67 percent of world exports. Exports will be driven by Asian countries, which remain very competitive and are expected to benefit from growing investment in the aquaculture sector. In 2021, 55 percent of world fish exports for human consumption will originate from Asia, with China as the world's leading exporter.

The main issues and uncertainties that might affect the fishery sector and, as a consequence, the projections are summarized below.

The next decade is likely to see major changes in the macroeconomic environment, international trade rules and tariffs, market characteristics, resources and social conduct. Their effects may influence fish markets in the medium term. Climate change impacts may also bring increasing uncertainty in many food sectors and might represent a compounding threat to the sustainability of capture fisheries and aquaculture development. These possible events take place in the context of other global social and economic pressures on natural resources and ecosystems, including environmental degradation and increasing land and water scarcity. New climate adaptation approaches will probably have to be integrated into the processes of improving fisheries governance. Action may also be required to secure conservation of aquatic ecosystems and safeguard stocks and productivity through technological innovation, investment in research and development (R&D), and a more closely controlled approach to fisheries management. Moreover, increased risks of species

Figure 48

Fishery production in live weight equivalent



Source: OECD and FAO Secretariats.

invasions and the spread of diseases raise additional concerns. Fish diseases could have major impacts on supply, demand and trade in domestic and international markets, as resulting trade restrictions might alter markets for extended periods.

Considerable benefits can accrue from rebuilding fisheries, an urgent task that is high on the international policy agenda. The OECD Committee for Fisheries decided to contribute to efforts by its Member States to rebuild their fisheries, where needed, by providing an analysis of the main policy issues. The focus was on rebuilding fisheries, which is a broader approach than rebuilding fish stocks, and took into consideration the social, economic and environmental dimensions. The outcome of this project, the study *The Economics of Rebuilding Fisheries*, is a set of principles and guidelines that help policy-makers in their rebuilding efforts, taking into account the economic and institutional aspects.[42] These practical and evidence-based principles and guidelines aim to ensure that rebuilding plans are examples of good governance, which implies inclusiveness, empowerment, transparency, flexibility and predictable sets of rules and processes. Rebuilding of fisheries may imply a change in fisheries management settings and reform towards the use of market-based instruments. The principles and guidelines have been adopted as an OECD Council Recommendation.

As production from capture fisheries has remained virtually constant, further aquaculture growth will be needed to meet the rising global demand for seafood. However, many constraints might affect the production prospects for this sector. They include the growing scarcity of water and limited opportunities for sites for new operations given the multiple users of coastal and riparian areas, the carrying capacity of the environment for nutrient and pollution loading and a less permissive regulatory environment. Unless guided and monitored adequately, aquaculture expansion may contribute to environmental problems, including degradation of land and marine habitats, chemical pollution, endangering biodiversity through escapees, and reduction of fish resistance to diseases. Inadequate biosecurity measures and disease outbreaks could also cause large economic losses to the sector. Meeting the future demand for food from aquaculture will also depend on the availability of inputs, including fish seeds[43] as well as of feeds in the requisite quality and quantities. Continued progress in developing terrestrially sourced substitutes for fishmeal and oils will help support continued growth in aquaculture.

Consumer concerns related to issues such as animal welfare, food quality, production and processing methods may cause further uncertainties in the fish sector. Especially in the more affluent markets, consumers are increasingly requiring high standards of quality assurance and demanding guarantees that the fish they purchase are produced sustainably. The stringent quality- and safety-related import standards, together with requirements for products meeting international animal health and environmental standards and social responsibility requirements, might act as barriers to small-scale fish producers and operators attempting to penetrate international markets and distribution channels. Future prices might be influenced not only by higher feed prices but also by the introduction of more rigorous regulations on the environment, food safety, traceability and animal welfare.

NOTES

1 Windle, M.J.S., Neis, B., Bornstein, S. and Navarro, P. 2006. *Fishing occupational health and safety: a comparative analysis of regulatory regimes* [online]. St. John's, Canada, SafetyNet, Memorial University of Newfoundland. [Cited 6 December 2011]. www.safetynet.mun.ca/pdfs/CARR.pdf
Wiseman, M. and Burge, H. 2000. *Fishing vessel safety review (less than 65 feet).* St. John's, Canada, Maritime Search and Rescue Newfoundland Region.
Petursdottir, G., Hannibalsson, O. and Turner, J. 2001. *Safety at sea as an integral part of fisheries management*. FAO Fisheries Circular No. 966. Rome, FAO. 39 pp. (also available at www.fao.org/docrep/003/x9656e/x9656e00.htm).
Jensen, O. 1997. Health hazards while fishing in heavy weather. *Occupational and Environmental Medicine*, 54(2): 141.

2 Kaplan, I.M. and Kite-Powell, H.L. 2000. Safety at sea and fisheries management: fishermen's attitudes and the need for co-management. *Marine Policy*, 24(6): 493–497.

3 Lincoln, J. and Knapp, G. (forthcoming). *Synthesis of case studies: effects of fisheries management policies on fishing safety.* FAO Fisheries Circular No. 1073. Rome, FAO.

4 FAO. 1995. *Code of Conduct for Responsible Fisheries.* Rome. 41 pp. (also available at www.fao.org/docrep/005/v9878e/v9878e00.HTM).

5 Op. cit. see note 1, Petursdottir, Hannibalsson and Turner (2001).

6 Op. cit. see note 1, Windle *et al*. (2006, p. 14).

7 Op. cit. see note 1, Wiseman and Burge (2000, p B5).

8 Op. cit. see note 1, Petursdottir, Hannibalsson and Turner (2001, p. 25).

9 National Oceanic and Atmospheric Administration. 2011. National Standard 10 Guidelines: a proposed rule by the National Oceanic and Atmospheric Administration on 04/21/2011. In: *Federal Register* [online]. [Cited 6 December 2011]. www.federalregister.gov/articles/2011/04/21/2011-9718/national-standard-10-guidelines

10 Huss, H.H. 1994. *Assurance of seafood quality*. FAO Fisheries Technical Paper No. 334. Rome, FAO. 169 pp.

11 Huss, H.H., Ababouch, L. and Gram, L. 2004. *Assessment and management of seafood safety and quality*. FAO Fisheries Technical Paper No. 444. Rome, FAO. 230 pp.

12 Ababouch, L. and Karunasagar, I. (forthcoming). *Seafood safety and quality: current practices and emerging issues.* FAO Fisheries and Aquaculture Technical Paper No. 574. Rome, FAO.

13 World Health Organization. 2007. Food safety and foodborne illness. In: *World Health Organization* [online]. [Cited 30 November]. www.who.int/mediacentre/factsheets/fs237/en/index.html

14 The Food Hygiene Regulations include Regulation EC/852/2004, which lays down the general hygiene requirements for all food business operators, and Regulation EC/853/2004, which lays down additional specific requirements for food businesses dealing with foods of animal origin, including live bivalve molluscs and fishery products. Regulation EC/854/2004 lays down the official controls for foods of animal origin. The basis for the Regulations is set down by the General Food Law Regulation EC/178/2002, which provides a framework to ensure a coherent approach in the development of food legislation.

15 FAO. 2011. *Fisheries management. 4. Marine protected areas and fisheries*. FAO Technical Guidelines for Responsible Fisheries No. 4, Suppl. 4. Rome. 198 pp.

16 Sanders, J.S., Gréboval, D. and Hjort, A., comps. 2011. *Marine protected areas: country case studies on policy, governance and institutional issues*. FAO Fisheries and Aquaculture Technical Paper No. 556/1. Rome, FAO. 118 pp.

17 The term "low-value fish" is preferred to "trash fish".

18 Tacon, A.G.J., Hasan, M.R. and Metian, M. 2011. *Demand and supply of feed ingredients for farmed fish and crustaceans: trends and prospects*. FAO Fisheries and Aquaculture Technical Paper No. 564. Rome, FAO. 87 pp.
19 FAO. 2011. FishStat Plus – universal software for fishery statistical time series. In: *FAO Fisheries and Aquaculture Department* [online]. Rome. [Cited 20 December 2011]. www.fao.org/fishery/statistics/software/fishstat/en
20 Typically, a farm-made aquafeed is a feed produced by farmers or small-scale feed manufacturers using some form of processing on-farm or in a small processing plant, resulting in a moist dough or a simple moist or dry pellet.
21 An industrially manufactured compound aquafeed consists of a number of ingredients mixed in various proportions to complement one another to form a nutritionally complete compound diet.
22 De Silva, S.S. and Hasan, M.R. 2007. Feeds and fertilizers: the key to long-term sustainability of Asian aquaculture. *In* M.R. Hasan, T. Hecht, S.S. De Silva and A.G.J. Tacon, eds. *Study and analysis of feeds and fertilizers for sustainable aquaculture development*, pp. 19–47. FAO Fisheries Technical Paper No. 497. Rome, FAO. 510 pp.
23 Op. cit., see note 19.
24 Rana, K.J., Siriwardena, S. and Hasan, M.R. 2009. *Impact of rising feed prices on aquafeeds and aquaculture production*. FAO Fisheries and Aquaculture Technical Paper No. 541. Rome, FAO. 63 pp.
25 Avnimelech, Y. 2009. *Biofloc technology – a practical guide book.* Baton Rouge, USA, World Aquaculture Society. 181 pp.
26 Washington, S. and Ababouch, L. 2011. *Private standards and certification in fisheries and aquaculture: current practice and emerging issues*. FAO Fisheries and Aquaculture Technical Paper No. 553. Rome, FAO. 181 pp.
27 FAO. 1998. *Report of the Technical Consultation on the Feasibility of Developing Non-Discriminatory Technical Guidelines for Eco-Labelling of Products from Marine Capture Fisheries. Rome, Italy, 21–23 October 1998.* FAO Fisheries Report No. 594. Rome. 29 pp.
28 FAO has concentrated on ISO Type I environmental labels, which are voluntary and based on third-party assessment of the environmental impact of the production system. ISO Type II and Type III ecolabels are self-declared statements of compliance with previously established indices, i.e. no independent confirmation of product claims. Although ISO Type II and Type III are not the subject of FAO guidelines, they are often high-profile types of labels and are becoming increasingly widespread.
29 FAO. 2009. *Guidelines for the Ecolabelling of Fish and Fishery Products from Marine Capture Fisheries. Revision 1. Directives pour l'étiquetage écologique du poisson et des produits des pêches de capture marines. Révision 1. Directrices para el ecoetiquetado de pescado y productos pesqueros de la pesca de captura marina. Revisión 1*. Rome/Roma. 97 pp.
30 FAO. 2011. *Guidelines for the Ecolabelling of Fish and Fishery Products from Inland Capture Fisheries. Directives pour l'étiquetage écologique du poisson et des produits des pêches de capture continentales. Directrices para el ecoetiquetado de pescado y productos pesqueros de la pesca de captura continental*. Rome/Roma. 106 pp.
31 FAO. 2011. *Technical Guidelines on Aquaculture Certification. Directives techniques relatives à la certification en aquaculture. Directrices técnicas para la certificación en la acuicultura*. Rome/Roma. 122 pp.
32 For introductions, see www.msc.org/documents/scheme-documents/msc-scheme-requirements/msc-certification-requirement-v1.1/view [cited 6 February 2012] and for enhancements, see www.msc.org/documents/scheme-documents/msc-scheme-requirements/directives/TAB_D_001_Enhanced_Fisheries.pdf/view [cited 6 February 2012].
33 Op. cit., note 29.

34 FAO. 2010. *Report of the Expert Consultation on the Development of Guidelines for the Ecolabelling of Fish and Fishery Products from Inland Capture Fisheries. Rome, 25–27 May 2010*. FAO Fisheries and Aquaculture Report No. 943. Rome. 37 pp.
35 Beuchelt, T.D. and Zeller, M. 2011. Profits and poverty: certification's troubled link for Nicaragua's organic and fairtrade coffee producers. *Ecological Economics*, 70(7): 1316–1324.
36 Op. cit., note 26.
37 This highlight article is based on the chapter on fish in the most recent edition of the *OECD–FAO Agricultural Outlook: OECD/FAO. 2012*. OECD–FAO Agricultural Outlook 2012. Paris, OECD Publishing. DOI : 10.1787/agr_outlook-2012-en
38 More information on the OECD–FAO AGLINK–COSIMO Projection System is available at www.agri-outlook.org/
39 The baseline is deterministic and assumes normal weather and production conditions, with the exception of the impact of the El Niño phenomenon set in the model for selected Latin American countries in 2015 and 2020.
40 That share will be lower in years of El Niño events (set in the model in 2015 and 2020) owing to reduced catches of anchoveta.
41 The reference point is low because of the El Niño event in 2010.
42 Organisation for Economic Co-operation and Development. 2010. *The Economics of Rebuilding Fisheries: Workshop Proceedings*. Paris. 268 pp.
43 The term fish seeds indicates eggs, spawn, offspring, progeny or brood of the aquatic organism (including aquatic plants) being cultured. At this infantile stage, seed may also be referred to or known as fry, larvae, postlarvae, spat and fingerlings. They may originate from two principal sources: from captive breeding programmes, or caught from the wild.