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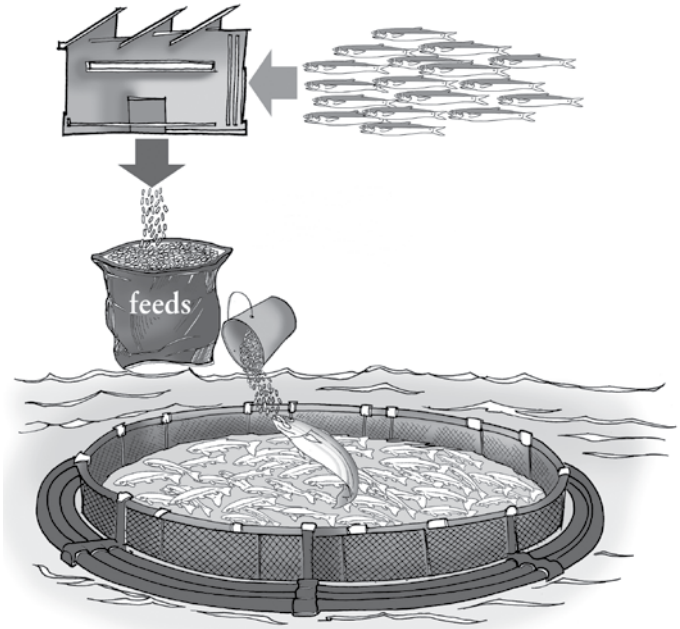
FAO TECHNICAL GUIDELINES FOR RESPONSIBLE FISHERIES

5

Suppl. 5

AQUACULTURE DEVELOPMENT

5. Use of wild fish as feed in aquaculture



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AQUACULTURE DEVELOPMENT

5. USE OF WILD FISH AS FEED IN AQUACULTURE

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
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PREPARATION OF THIS DOCUMENT

These technical guidelines have been prepared by the Fisheries and Aquaculture Department of the Food and Agriculture Organization of the United Nations (FAO) under the coordination of Mohammad R. Hasan and are based on the outputs of the FAO Expert Workshop on the Use of Wild Fish and/or Other Aquatic Species as Feed in Aquaculture and its Implications to Food Security and Poverty Alleviation that was held in Kochi, India, 16–18 November 2007. The participating experts included B. Vishnu Bhat, Aliro R. Bórquez, Cécile Brugère, Chris Carter, Sena S. De Silva, Simon Funge-Smith, Nyoman A. Giri, Brett Glencross, Matthias Halwart, Mohammad R. Hasan, Thomas Hecht, Adrián J. Hernández, Tim Huntington, Andrew Jackson, G. Mohan Kumar, D.D. Nambudiri, M.C. Nandeesha, Sih Yang Sim, Victor Suresh, Albert G.J. Tacon, Giovanni M. Turchini, Shyam P. Vemuri and P.N. Vinod.

These guidelines are a further contribution towards the implementation of the provisions of the FAO Code of Conduct for Responsible Fisheries (the Code) and thus have no formal legal status. Although the Code does not address issues related to the use of wild fish as feed in aquaculture, the need for guidance in these matters is recognized. *Inter alia*, the Code strongly emphasizes the need for responsible fisheries and aquaculture development, equitable international trade, and the protection of the environment and aquatic biodiversity. The information presented is meant to assist with consideration of issues related to the implementation of the provisions of the Code. Furthermore, any differences in the terminology employed should not be considered as a reinterpretation of the Code. These guidelines are intended to be flexible and capable of evolving as circumstances change or as new information becomes available.

The initial drafts of these technical guidelines were compiled by Sunil N. Siriwardena (FAO Consultant). Additional contributions and/or comments were provided by J. Richard Arthur, Devin Bartley, Gabriella Bianchi, Cécile Brugère, Pedro Bueno, Sena S. De Silva, Simon Funge-Smith, Matthias Halwart, Thomas Hecht, Iddya Karunasagar, John Moehl, Thomas Moth-Poulsen, Alejandro F. Nava, Ulf Wijkström, Rolf Willmann and Raymon van Anrooy. Marianne Guyonnet is acknowledged for her assistance in quality control and FAO house style and José Luis Castilla Civit for the layout design. Jiansan Jia, Chief of the Aquaculture Service, FAO is acknowledged for his support throughout the process. The contribution by the Government of Japan, which enabled FAO to prepare for and hold the expert workshop, is gratefully acknowledged.

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ABSTRACT

These technical guidelines on the use of wild fish as feed in aquaculture have been developed in support of Article 7 (responsible fisheries management) and Article 9 (aquaculture development) of the FAO Code of Conduct for Responsible Fisheries, and in particular in support of Articles 9.1.3, 9.1.4 and 9.4.3. The objectives of the guidelines are to contribute towards the development of aquaculture and the sustainable utilization of feed-fish stocks. The guidelines cover a number of issues relevant to the use of wild fish in feeds in aquaculture, including ecosystem and environmental impacts, ethical considerations on the responsible use of fish as feed, aquaculture technology and development, and statistics and information needs for managing the development of aquaculture. Specific matters relating to the management of fishery resources that may be used as feeds are briefly considered in these guidelines, as these have been dealt with in detail in separate FAO guidelines relating to fisheries management and which, *inter alia*, would also apply to feed-fish fisheries. The guiding principles for these technical guidelines were developed and adopted at the FAO Expert Workshop on the Use of Wild Fish and/or Other Aquatic Species as Feed in Aquaculture and its Implications to Food Security and Poverty Alleviation, 16–18 November 2007, Kochi, India.

CONTENTS

ABBREVIATIONS AND ACRONYMS

ACFM	Advisory Committee on Fishery Management
BMP	better management practice
CCRF	Code of Conduct for Responsible Fisheries
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
COFI	Committee on Fisheries
CPUE	catch per unit effort
CSD	Commission on Sustainable Development
EAF	ecosystem approach to fisheries
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
FCR	feed conversion ratio
GAA	Global Aquaculture Alliance
GAFTA	Grain and Feed Trade Association
GFCM	General Fisheries Commission for the Mediterranean
GMP	good manufacturing practice
HACCP	Hazard Analysis and Critical Control Point (system)
ICCAT	International Commission on Conservation of Atlantic Tuna
ICES	International Council for the Exploration of the Sea
IFFO	International Fishmeal and Fish Oil Organisation
FIN	Fishmeal Information Network
IUU	Illegal, unregistered and unreported (fishing)
MPA	marine protected area
MSC	Marine Stewardship Council
NGO	non-governmental organization
PCB	polychlorinated biphenol
PCDD	polychlorinated dibenzo-para dioxin
PCDF	polychlorinated dibenzofuran
POP	persistent organic pollutant
RFMO	regional fisheries management organization
RFO	regional fisheries organization
SCSA	GFCM's Sub-Committee on Stock Assessment
SDRS	sustainable development reference system
SFP	Sustainable Fisheries Partnership
TAC	total allowable catch
TSE	transmissible spongiform encephalopathy
TURF	territorial use rights in fisheries
UNCED	United Nations Conference on Environmental Development
UNCLOS	United Nations Convention on the Law of the Sea
UNFSA	United Nations Fish Stocks Agreement
WSSD	World Summit on Sustainable Development
WSSD-POI	World Summit on Sustainable Development Plan of Implementation
WWF	World Wide Fund for Nature

BACKGROUND

1. From ancient times, fishing from oceans, lakes and rivers has been a major source of food, and a provider of employment and other economic benefits for humanity. With increasing knowledge and the dynamic development of fisheries, it was realized that living aquatic resources, although renewable, were not infinite and needed to be properly managed if their contribution to the nutritional, economic and social well-being of the growing world's population was to be sustained.

2. For nearly three decades, because of the dramatic increase of pollution, illegal, unreported and unregulated fishing and other abusive fishing techniques worldwide, catches and landings have been shrinking and fish stocks declining, often at alarming rates.

3. Stock depletion has negative implications for food security and economic development and reduces social welfare, particularly in developing countries, where many people rely on fish as their main source of animal protein and income. Living aquatic resources need to be properly managed if their benefits to society are to be sustainable.

4. To maintain societal benefits, depleted stocks must be rebuilt and healthy stocks must be fished on a sustainable basis. Adoption of the United Nations Convention on the Law of the Sea, in 1982, provided the framework for improved management of marine resources.

5. Overexploitation of important fish stocks, modifications of ecosystems, significant economic losses, and international conflicts on management and fish trade still threaten the long-term sustainability of fisheries and the contribution of fisheries to food supply.

6. In light of this situation, FAO Member States have expressed the need to develop aquaculture as one of the ways with which to bridge the gap between capture fisheries output and the increasing world demand for fish and shellfish.

7. In the last three decades, aquaculture has grown rapidly and has developed into a globally robust and vital industry. However, aquaculture can have significant adverse environmental and social impacts.

8. Consequently, the Nineteenth Session of the FAO Committee on Fisheries (COFI), held in March 1991, recommended that new approaches to fisheries and aquaculture management embracing conservation and environmental, as well as social and economic considerations, were urgently needed. FAO was asked to develop the concept of responsible fisheries and elaborate a Code of Conduct to foster its application.

9. Subsequently, the Government of Mexico, in collaboration with FAO, organized an International Conference on Responsible Fishing in Cancún in May 1992. The Declaration of Cancún, endorsed at that Conference, was brought to the attention of the United Nations Conference on Environment and Development Summit in Rio de Janeiro, Brazil, in June 1992, which supported the preparation of a Code of Conduct for Responsible Fisheries (the Code). The FAO Technical Consultation on High Seas Fishing, held in September 1992, further recommended the elaboration of a code to address the issues regarding high seas fisheries.

10. The One Hundred and Second Session of the FAO Council, held in November 1992, discussed the elaboration of the Code, recommending that priority be given to high seas issues and requested that proposals for the Code be presented to the 1993 session of the COFI.

11. The Twentieth Session of the COFI, held in March 1993, examined in general the proposed framework and content for such a Code, including the elaboration of guidelines, and endorsed a time frame for the further elaboration of the Code. It also requested FAO to prepare, on a "fast track" basis, as part of the Code, proposals to prevent reflagging of fishing vessels which affect conservation and management measures on the high seas. This resulted in the FAO Conference, at its Twenty-seventh Session in November 1993, adopting the Agreement to Promote Compliance with International Conservation and Management Measures by Fishing Vessels on the High Seas, which, according to FAO Conference Resolution 15/93, forms an integral part of the Code. It was also recognized and confirmed that issues of responsible aquaculture development and aquaculture sustainability should be addressed in the formulation process so that these be appropriately covered in the envisaged Code.

12. The implicit recognition of the importance of governance in aquaculture is underlined in Article 9.1.1 of the Code, which requires States to "establish, maintain and develop an appropriate legal and administrative framework to facilitate the development of responsible aquaculture". In addition, at the beginning of the new millennium, there has been growing

recognition of the significant potential for the use of ocean and coastal waters for mariculture expansion. The outstanding issue in this area is that the existing applicable principles of public international law and treaty provisions provide little guidance on the conduct of aquaculture operations in these waters. Yet, experts agree that most of the future aquaculture expansion will occur in the seas and oceans, certainly further offshore, perhaps even as far as the high seas. The regulatory vacuum for aquaculture in the high seas would have to be addressed should aquaculture operations expand there.

13. The Code was formulated so as to be interpreted and applied in conformity with the relevant rules of international law, as reflected in the 10 December 1982 United Nations Convention on the Law of the Sea. The Code is also in line with the Agreement for the Implementation of the Provisions of this Law, namely the 1995 Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks. It is equally in line with, *inter alia*, the 1992 Declaration of Cancún and the 1992 Rio Declaration on Environment and Development, in particular Chapter 17 of Agenda 21.

14. The development of the Code was carried out by FAO in consultation and collaboration with relevant United Nations Agencies and other international organizations, including non-governmental organizations.

15. The Code consists of five introductory articles: Nature and scope; Objectives; Relationship with other international instruments; Implementation, monitoring and updating; and Special requirements of developing countries. These introductory articles are followed by an article on General principles, which precede the six thematic articles on Fisheries management, Fishing operations, Aquaculture development, Integration of fisheries into coastal area management, Post-harvest practices and trade, and Fisheries research. As already mentioned, the Agreement to Promote Compliance with International Conservation and Management Measures by Fishing Vessels on the High Seas forms an integral part of the Code.

16. The Code is voluntary. However, certain parts of it are based on relevant rules of international law, as reflected in the United Nations Convention on the Law of the Sea of 10 December 1982. In capture fisheries, the Code also contains provisions that may be or have already been given binding effect by means of other obligatory legal instruments amongst the Parties, such as the Agreement to Promote Compliance with Conservation and Management Measures by Fishing Vessels on the High Seas, 1993. In aquaculture, the provisions of the Code implicitly encourage participatory governance of the sector, which extends from industry self-regulation, to

co-management of the sector by industry representatives and government regulators and to community partnerships. Compliance is self-imposed or enforced by peer pressure, with industry organizations having the ability to exclude those who do not comply coupled to periodic inspections by government regulators.

17. The Twenty-eighth Session of the Conference in Resolution 4/95 adopted the Code of Conduct for Responsible Fisheries on 31 October 1995. The same Resolution requested FAO *inter alia* to elaborate appropriate technical guidelines in support of the implementation of the Code in collaboration with Members and interested relevant organizations.

18. The expanding role and increasing contribution of aquaculture to economic growth, social welfare as well as global food security was recognized and reiterated at international levels such as the 1995 FAO/ Japan Conference on the Contribution of Fisheries and Aquaculture to Food Security, the 1996 World Food Summit, the 1999 Ministerial Meeting on Fisheries, the 2000 FAO/NACA (Network of Aquaculture Centres in Asia and the Pacific) Conference on Aquaculture in the Third Millennium and its Bangkok Declaration and Strategy, and most recently, the 2009 World Summit on Food Security.

19. The application of the ecosystem approach to fisheries and aquaculture as strategies for the development of the sector contributes to the implementation of the provisions of the Code, thereby enforcing the technical, ecological, economic and social sustainability of the industry.

1. INTRODUCTION

These technical guidelines on the use of wild fish as feed in aquaculture have been developed to support Articles 7 and 9, in particular Articles 9.1.3[1], 9.1.4[2] and 9.4.3[3] of the FAO's Code of Conduct for Responsible Fisheries (CCRF) The objective of these guidelines is to provide assistance in ensuring the orderly and sustainable development of aquaculture and the equitable and sustainable use of wild fish stocks.

1.1 Statement of purpose

The purpose of the technical guidelines is to provide guidance on the responsible use of wild fish as feed in aquaculture. The guidelines consider a range of issues that are relevant for the use of wild fish as feed in aquaculture, including: a) fisheries management; b) policy development; c) food security; d) poverty alleviation; e) social and ethical issues; and f) aquaculture technology and development. There are extensive national and international management frameworks already in place for various aspects of fisheries management. These cover issues such as the ecosystem approach to fisheries (EAF), initiatives on improved sustainable management of feed-fish stocks, and development of indicators to measure the sustainability of feed-fish fisheries and to avoid duplication; thus, these are not considered here. Where appropriate, these guidelines will refer to the relevant articles of the CCRF that cover fisheries management.

Implementation of the technical guidelines may be undertaken by any entity that is competent or has the responsibility to do so. These may include, *inter alia*, governments, non-governmental organizations (NGOs), private-sector groups (e.g. producers, feed manufacturers, processors, traders, farmers and professional associations), civil society and consortia comprising some or all of these stakeholder groups.

1.2 Structure and content of this document

The guiding principles used in this document were developed at the FAO Expert Workshop on "Use of Wild Fish and/or Other Aquatic Species as Feed

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[1] CCRF Article 9.1.3: States should produce and regularly update aquaculture development strategies and plans, as required, to ensure that aquaculture development is ecologically sustainable and to allow the rational use of resources shared by aquaculture and other activities.

[2] CCRF Article 9.1.4: States should ensure that the livelihoods of local communities, and their access to fishing grounds, are not negatively affected by aquaculture developments.

[3] CCRF Article 9.4.3: States should promote efforts which improve selection and use of appropriate feeds, feed additives and fertilizers, including manures.

in Aquaculture and its Implications to Food Security and Poverty Alleviation", 16–18 November 2007, Kochi, India.

The guiding principles are arranged under five key issues as identified in the workshop: a) fisheries management considerations, b) ecosystem and environmental impacts, c) ethical issues and responsible use, d) aquaculture technology and development, and e) statistics and information needs for management. Each guiding principle is supported by an introductory explanation followed by a suite of technical guidelines for the implementation of and compliance with the principle.

1.3 Terms and definitions

For the purpose of these technical guidelines on the "Use of Wild Fish as Feed in Aquaculture", the following terms and definitions apply:

Aquaculture: The farming of aquatic organisms including fish, molluscs, crustaceans and aquatic plants. Farming implies some sort of intervention in the rearing process to enhance production, such as regular stocking, feeding, protection from predators, etc. Farming also implies individual or corporate ownership of the stock being cultivated (FAO, 1997a). Also defined as the farming of aquatic organisms in inland and coastal areas, involving intervention in the rearing process to enhance production and the individual or corporate ownership of the stock being cultivated (FAO Glossary of Aquaculture, available at: www.fao.org/fi/glossary/aquaculture/).

Aquatic animals: All life stages (including eggs and gametes) of fish, molluscs, crustaceans and amphibians originating from aquaculture establishments or removed from the wild for farming purposes, for release into the environment, for human consumption or for ornamental purposes (OIE, 2010).

Artisanal fisheries: Traditional fisheries involving fishing households (as opposed to commercial companies), using relatively small amounts of capital and energy, relatively small fishing vessels (if any), making short fishing trips, close to shore, mainly for local consumption. In practice, definition varies between countries, e.g. from gleaning or a one-person canoe in poor developing countries, to trawlers, seiners, or long-liners longer than 20 m in developed ones. Artisanal fisheries can be subsistence or commercial fisheries, providing for local consumption or export. Artisanal fisheries are sometimes referred to as small-scale fisheries (FAO Fisheries Glossary, available at: www.fao.org/fi/glossary/default.asp).

Bait fish: Bait fish is a term used for small fish that are used as bait to catch larger fish or alternatively bait fish are small fish that attract larger predators. Other definition: live fish (e.g. minnows, tilapia, goldfish) that are produced commercially in aquaculture to be used as live bait.

Best/better management practices (BMPs): Management practices aimed at improving the quantity, safety and quality of products taking into consideration animal health and welfare, food safety, environmental and socio-economical sustainability. BMP implementation is generally voluntary. The term "better" is preferred rather than "best" because aquaculture practices are continuously improving (today's "best" is tomorrow's "norm") (FAO, 2010d).

Biological diversity or biodiversity: The variability among living organisms from all sources including, *inter alia*, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems. Diversity indices are measures of richness (the number of species in a system); and to some extent, evenness (variances of species' local abundance). They are therefore indifferent to species substitutions, which, however, may reflect ecosystem stresses (such as those due to high fishing intensity) (FAO, 1997b). Also defined as the variability among living organisms from all sources, including, *inter alia*, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part (CBD, 1992).

Biosecurity: Broadly speaking, "biosecurity" in food and agriculture describes the concept and process of managing – in a holistic manner – biological risks associated with food and agriculture (in the broadest sense, i.e. including agronomy, livestock husbandry, forestry, fisheries and related environmental aspects). This usage also implies that transboundary movements or the use of novel genotypes are involved in some way (Cock, 2003).

Bycatch: Part of a catch of a fishing unit taken incidentally in addition to the target species towards which fishing effort is directed. Some or all of it may be returned to the sea as discards, usually dead or dying (FAO Fisheries Glossary, available at: www.fao.org/fi/glossary/default.asp).[4]

[4] It is not possible to develop a standard international definition of bycatch because of the very diverse nature of the world's fisheries, historical differences in how bycatch has been defined nationally, ambiguities associated with bycatch-related terminologies, and choices of individual fishers on how different portions of their catch will be used (FAO, 2011).

Certification: Procedure by which an official certification body or officially recognized certification body gives written or equivalent assurance that a product, process or service conforms to specified requirements. Certification may be, as appropriate, based on a range of audit activities that may include continuous audit in the production chain (FAO, 2005a). Also defined as procedure by which accredited certification bodies, based on an audit, provide written or equivalent assurance that food safety management systems and their implementation conform to requirements (GFSI, 2007).

Commercial/industrial aquafeed: An aquafeed comprised of a number of ingredients that are mixed in various proportions to complement one another to form a nutritionally complete compound diet. Such feeds are manufactured in industrial feed milling plants and are distributed and sold using conventional market chains. Commercial aquafeeds are commonly produced in different forms: compressed sinking pellet, extruded floating pellet or crumble, extruded soft pellet (FAO, 2010c).

Complete feed: A nutritionally adequate feed for animals other than humans; by specific formula is compounded to be fed as the sole ration and is capable of maintaining life and/or promoting production without any additional substance being consumed except water (FAO, 2001).

Compound feed: A mixture of products of vegetable or animal origin in their natural state, fresh or preserved, or products derived from the industrial processing thereof, or organic or inorganic substances, whether or not containing additives, for oral feeding in the form of a complete feed (FAO, 2001).

Conservation: The management of human use of the biosphere so that it may yield the greatest sustainable benefit to current generations while maintaining its potential to meet the needs and aspirations of future generations; thus, conservation is positive, embracing preservation, maintenance, sustainable utilization, restoration and enhancement of the natural environment (WRI, 1992).

Crumbled, crumbling (process): Pellets reduced to granular form (FAO, 2001).

Diet: Feed ingredients or a mixture of ingredients including water that is consumed by animals (FAO, 2001).

Discards: That component of a catch thrown back after capture. Normally, most of the discards can be assumed not to survive (FAO, 1997b).

Ecolabel: A seal of approval (or certification) of a product, process or service complying with a particular set of agreed environmental criteria, usually awarded by an impartial third party (certification body). In fisheries, the label informs on the quality of the product itself as well as on the production and management processes (FAO, 2003).

Ecolabelling: A voluntary method of certification of environmental quality (of a product) and/or environmental performance of a process based on lifecycle considerations and agreed sets of criteria and standards (FAO, 2003).

Ecosystem: An organizational unit consisting of an aggregation of plants, animals (including humans) and micro-organisms, along with the non-living components of the environment (FAO, 2003).

Extrusion (process): A process by which feed has been pressed, pushed or protruded through orifices under pressure (FAO, 2001).

Farm-made aquafeed: Typically a feed that is 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. Farm-made aquafeed produced by the farmers is often synonymously termed "home-made aquafeed". Also defined as fish feed made by farmers as well as small- and medium-scale feed manufacturers (Hasan *et al*., 2007).

Feed(s): Edible materials(s) that are consumed by animals and contribute energy and/or nutrients to the animals' diet. Usually refers to animals rather than humans (FAO, 2001).

Feed additives: Chemicals, other than nutrients, that are required by the fish and that are approved for addition to their feed (FAO/WHO, 2009). Also defined as an ingredient or combination of ingredients added to the basic feed mix or parts thereof to fulfil a specific need. Usually used in micro quantities and requiring careful handling and mixing (FAO, 2001).

Feed conversion ratio (FCR): Ratio between the dry weight of feed fed and the weight of yield gain. Measure of the efficiency of conversion of feed to fish (e.g. FCR = 2.8 means that 2.8 kg of feed is needed to produce 1 kg of fish live weight). (FAO Glossary of Aquaculture, available at: www.fao.org/fi/glossary/aquaculture/default.asp). Two additional terms are used by the farmer, the biological FCR and the economic FCR. Biological FCR is the net amount of feed used to produce 1 kg of fish, while the economic FCR takes into account all the feed used, including losses through wastage and fish

mortalities (modified after Aquamedia, available at: www.piscestt.com/home/FAQ/Answers/ans8_en.asp).

Feed fish: Fish (or any other aquatic species) of whatever kind used for animal/aquaculture feeds, either processed into fishmeal or fish oil or used in fresh form (FAO, 2008).

Feed-fish fishery: A dedicated fishery that catches fish for use as feed in aquaculture/animal feed that are either processed into fishmeal or fish oil or used in fresh form (FAO, 2008).

Fish (= all aquatic animal species): Literally, a cold-blooded lower vertebrate that has fins, gills and scales (usually) and lives in water. Used as a collective term and includes molluscs, crustaceans and any aquatic animal that is harvested (FAO Glossary of Aquaculture, available at: www.fao.org/fi/glossary/aquaculture/default.asp).

Fishery: The term "fishery" can refer to the sum of all fishing activities on a given resource, for example, a hake or shrimp fishery. It may also refer to the activities of a single type or style of fishing on a particular resource, for example a beach seine fishery or trawl fishery. The term is used in both senses in this document and, where necessary, the particular application is specified (FAO, 2003).

Fisheries management organizations: The institutions responsible for fisheries management, including the formulation of the rules that govern fishing activities. The fishery management organization and its subsidiary bodies may also be responsible for all ancillary services, such as: collecting information; assessing stocks; conducting monitoring, control and surveillance (MCS) and consultations with stockholders; and applying and/or determining the rules access to the fishery, and for resource allocation (FAO, 1997b).

Fish feed: Fodder intended for fish in aquaculture establishments, in any form and of any composition (FAO/WHO, 2009). Also defined as any material (single or multiple), whether processed, semi-processed or raw, that is intended to be fed directly to aquatic animals (OIE, 2010).

Fishmeal: Protein-rich meal derived from processing whole fish (usually small pelagic fish and bycatch) as well as residues and by-products from fish processing plants (fish offal) (FAO Glossary of Aquaculture, available at: www.fao.org/fi/glossary/aquaculture/default.asp).

Fish oil: Oil extracted from whole fish or from fish waste (FAO Glossary of Aquaculture, available at: www.fao.org/fi/glossary/aquaculture/default.asp).

Fish stock (also fish/fishery resource): The living resources in the community or population from which catches are taken in a fishery. Use of the term "fish stock" usually implies that the particular population is more or less isolated reproductively from other stocks of the same species and is thus self-sustaining (FAO, 1997b).

Fleet: The total number of units of any discrete type of fishing activity using a specific resource. Hence, for example, a fleet may be all the purse seine vessels in a specific sardine fishery, or all the fishers setting nets from the shore in a tropical multispecies fishery (FAO, 2003).

Forage species: Species used as prey by a predator for its food (FAO Fisheries Glossary, available at: www.fao.org/fi/glossary/default.asp). Forage fish include small and medium-sized pelagic species such as anchovy, sardine, herring, menhaden, mackerel and capelin, but they also include squid, shrimp, and krill.

Formulated feed: Two or more feed ingredients proportioned, mixed and processed according to certain specifications (FAO Glossary of Aquaculture, available at: www.fao.org/fi/glossary/aquaculture/default.asp).

Growth overfishing: Occurs when too many small fish are being harvested too early, through excessive fishing effort and poor selectivity (e.g. too small mesh sizes) and the fish are not given enough time to grow to the size at which the maximum yield-per-recruit from the stock would be obtained. A reduction of fishing mortality on juveniles, or their outright protection, would lead to an increase in yield from the fishery. Growth overfishing occurs when the fishing mortality rate is above F_{max} (in a yield-per-recruit model). This means that individual fish are caught before they have a chance to reach their maximum growth potential (FAO Fisheries Glossary, available at: www.fao.org/fi/glossary/default.asp).

Indicator: A variable that can be monitored in a system, e.g. a fishery, to give a measure of the state of the system at any given time. Each indicator should be linked to one or more reference points and used to track the state of the fishery in relation to those reference points (FAO, 2003).

Ingredient, feed ingredient: A component part or constituent of any combination or mixture making up a commercial feed (FAO, 2001). Also defined as a component, part or constituent of any combination or mixture

making up a feed, including feed additives, whether or not it has a nutritional value in the animal's diet. Ingredients may be of terrestrial or aquatic, plant or animal origin and may be organic or inorganic substances (OIE, 2010).

Mash (physical form): A mixture of ingredients in meal form (FAO, 2001).

Non-target species: Species for which the gear is not specifically set, although they may have immediate commercial value and be a desirable component of the catch (FAO Fisheries Glossary, available at: www.fao.org/fi/glossary/default.asp).

Overfishing: A generic term used to refer to the state of a stock subject to a level of fishing effort or fishing mortality such that a reduction of effort would, in the medium term, lead to an increase in the total catch. Often equated to biological overfishing, it results from a combination of growth overfishing and recruitment overfishing and often occurs together with ecosystem overfishing and economic overfishing (FAO Fisheries Glossary, available at: www.fao.org/fi/glossary/default.asp).

Pellets (physical form): Agglomerated feed formed by compacting and forcing through die openings by a mechanical process (FAO, 2001).

Precautionary approach: A set of agreed measures and actions, including future courses of action, that ensures prudent foresight and reduces or avoids risk to the resource, the environment, and the people, to the best extent possible, taking into account existing uncertainties and the potential consequences of being wrong (adapted from FAO, 2003).

Quota: A share of the total allowable catch (TAC) allocated to an operating unit such as a country, a community, a vessel, a company or an individual fisher (individual quota) depending on the system of allocation. Quotas may or may not be transferable, inheritable and tradable. While generally used to allocate TAC, quotas could be used also to allocate fishing effort or biomass (FAO, 2003).

Recruitment overfishing: A situation in which the rate of fishing is (or has been) such that annual recruitment to the exploitable stock has become significantly reduced. The situation is characterized by a greatly reduced spawning stock, a decreasing proportion of older fish in the catch, and generally very low recruitment year after year. If prolonged, recruitment overfishing can lead to stock collapse, particularly under unfavourable environmental conditions (FAO Fisheries Glossary, available at: www.fao.org/fi/glossary/default.asp).

Reduction fishery/fisheries: Generally regarded as a fishery / fisheries that is / are geared towards the reduction of the catch to fishmeal and/or fish oil (FAO, 2008).

Responsible aquaculture: Aquaculture conducted according to the principles provided in the FAO Code of Conduct for Responsible Fisheries (FAO, 1995).

Semi-commercial aquafeed: Feeds comprised of a number of ingredients that are mixed in various proportions to complement one another to form a simple compound feed. Such feeds are manufactured using simple production technologies such as grinding, cooking and drying, and are distributed and sold via local market chains. Aquafeeds in this category may be made by the farmers or by small- and medium-scale feed manufacturers (FAO, 2010c).

Small-scale aquaculture: Aquaculture systems with a small annual production (maximum of one tonne per unit and 10 tonnes total) that are comprised of one or more small production units, family or communally operated, have low to moderate input levels and use limited external labour. (FAO Glossary of Aquaculture, available at: www.fao.org/fi/glossary/aquaculture/default.asp). Also defined as farming and husbandry of aquatic organisms to augment nutrition or income. The operation uses limited capital and family or household labour (SEAFDEC, 2005).

Small-scale farmers: Individuals or groups of individuals involved in aquaculture production that has a small volume of production or relatively small production area. These farmers may also have limited resources or assets and often have limited technical or financial capacity (adapted from FAO/NACA/Government of Thailand, 2007).

Small-/medium-scale feed manufacturer: An aquafeed manufacturer that produces simple formulated feeds using simple processing techniques such as grinding, cooking and drying to produce simple moist or dry pellets. Small-scale feed manufacturers may be farmers that are manufacturing feeds for their own use and to supply the local market. Feeds in this category may be referred to as “semi-commercial aquafeeds” or “farm-made feeds” (FAO, 2010c).

Socially responsible aquaculture: Aquaculture that is developed and operated in a responsible manner, i.e. that benefits the farm, the local communities and the country; that contributes effectively to rural development, and particularly poverty alleviation; has employees who are treated fairly; maximizes benefits

and equity; minimizes conflicts with local communities; ensures worker welfare and fair working conditions; minimizes risks to smallholders; and provides training to workers in responsible aquaculture practices (FAO/NACA/UNEP/WB/WWF, 2006).

Standard: A criterion (or indicator, or reference point) that has been formally established and is enforced by an authority and on the basis of which constraining action can be taken (FAO Fisheries Glossary, available at: www.fao.org/fi/glossary/default.asp). Also defined as a normative document, established by consensus and approved by a recognized body, that provides, for common and repeated use, rules, guidelines or characteristics for activities or their results, aimed at the achievement of the optimal degree of order in a given context (GFSI, 2007).

Stakeholder: Any person or group with a legitimate interest in the conservation and management of the resources being managed. Generally speaking, the categories of interested parties will often be the same for many fisheries, and should include contrasting interests: commercial/recreational, conservation/exploitation, artisanal/industrial, fisher/buyer-processor-trader as well as governments (local/state/national). The public and the consumers could also be considered as interested parties in some circumstances (FAO, 2003).

Stock: A group of individuals in a species occupying a well-defined spatial range independent of other stocks of the same species. Random dispersal and directed migrations due to seasonal or reproductive activity can occur. Such a group can be regarded as an entity for management or assessment purposes. Some species form a single stock (e.g. southern bluefin tuna) while others are composed of several stocks (e.g. albacore tuna in the Pacific Ocean comprises separate northern and southern stocks). The impact of fishing on a species cannot be fully determined without knowledge of the stock structure (FAO, 2003).

Sustainable development: Development that meets the needs of the present without compromising the ability of future generations to meet their own needs (FAO, 2003).

Sustainable use: The use of components of biological diversity in a way and at a rate that does not lead to the long-term decline of biological diversity, thereby maintaining its potential to meet the needs and aspirations of present and future generations (FAO, 2003).

Target species: Those species that are primarily sought by the fishers in a particular fishery. The subject of directed fishing effort in a fishery. There may be primary as well as secondary target species (FAO, 2003).

Traceability: The ability to follow the movement of a product of aquaculture or inputs such as feed and seed, through specified stage(s) of production, processing and distribution (FAO/WHO, 2010).

Trash fish/low-value fish: Fish that have a low commercial value by virtue of their low quality, small size or low consumer preference – they are either used for human consumption (often processed or preserved) or used for livestock/fish, either directly or through reduction to fishmeal/fish oil (Funge-Smith, Lindebo and Staples, 2005).

Wild fish: Fish that are obtained from capture fisheries.

2. OVERVIEW OF THE USE OF WILD FISH AS FEED IN AQUACULTURE AND RELATED ISSUES

2.1 Use of fish in feeds

In 2008, global aquaculture production reached 52.5 million tonnes (excluding aquatic plants), growing at an annual rate of 8.4 percent. Its proportional contribution to total food fisheries output increased from 3.9 percent in 1970 to 42.9 percent in 2008 (FAO, 2010a), indicating the important role it plays in supplying fish for human consumption.

There is an increasing trend for aquaculture to be dependent on feeds. In 2008, about 31.5 million tonnes or 46.1 percent of total global aquaculture production were dependent upon the direct use of feed, either as a single ingredient, as farm-made aquafeeds or by the use of industrially manufactured compound aquafeeds (FAO, 2010a). Total industrial compound aquafeed production increased almost four fold from 7.6 million tonnes in 1995 to 29.3 million tonnes in 2008, with production growing at an average rate of 10.9 percent per year (Tacon *et al.*, 2010). Commonly used key ingredients in aquafeeds are: a) protein sources: fishmeal, soybean meal, various oilseed cakes and meals; b) energy/carbohydrate sources: various cereals and cereal by-products; and c) lipids/oils: fish oil and vegetable oils (De Silva and Hasan, 2007). Compound feeds are used both for the production of lower-value (in marketing terms) food-fish species such as non-filter feeding carps, tilapia, catfish and milkfish (*Chanos chanos*), as well as higher-value species such as marine finfish, salmonids, marine shrimp, and freshwater eels and crustaceans.

Within the animal husbandry subsectors, aquaculture is now the largest user of fishmeal and fish oil. In 2007, aquaculture is estimated to have used 68.4 percent (3.84 million tonnes) of world fishmeal production and 81.3 percent (0.82 million tonnes) of fish oil production (Tacon *et al.*, 2010). In addition, Edwards, Tuan and Allan (2004) suggested that, globally, about five million tonnes of trash fish/low-value fish are used directly (i.e. as raw ingredients not reduced into fishmeal) as feed in aquaculture. In 2007, 20.4 million tonnes (22.4 percent of the global fish and shellfish landings) was reduced into fishmeal and fish oil (FAO, 2010a). Increased use of fishmeal and fish oil and trash fish/low-value fish in aquaculture can primarily be attributed to the increase in production of carnivorous species, particularly marine crustaceans, marine finfish, salmonids and other diadromous fishes (Rana, Siriwardena and Hasan, 2009). However, it is projected that over the next ten years or so, the total use of fishmeal by the aquaculture sector will decrease while the use of fish oil will probably remain around the 2007 level (Tacon *et al.*, 2010).

Fishmeal is produced through a reduction process where the fish are cooked, press-dried and milled into meal. Fish oil is a by-product of the process. On average, 4–5 kg of wet fish will yield 1 kg of fishmeal and 100 g of fish oil (De Silva and Anderson, 1995). The raw material used in industrial reduction processes consists mainly of low-value fish, often referred to as forage fish or feed fish, obtained from reduction fisheries and as bycatch[5] resulting mainly from food-fish trawling and artisanal fisheries. The biggest reduction fisheries are those in the southeast Pacific (e.g. Peruvian anchoveta fishery) and northwest Europe. Some of these fisheries also produce fish for human consumption (e.g. canned sardines and mackerel). While bycatch is a worldwide phenomenon, it is mainly in East Asia where it provides significant quantities of fish for aquaculture. The main artisanal feed-fish fisheries occur in the Asia-Pacific region (Wijkström, 2009).

Globally, the main species used for the manufacture of fishmeal and fish oil are small pelagic species such as anchoveta (*Engraulis ringens*), sand eels (*Ammodytes* spp.), Atlantic menhaden (*Brevoortia tyrannus*), capelin (Family Osmeridae, e.g. *Mallotus* spp.), Atlantic herring (*Clupea harengus harengus*), Norway pout (*Trisopterus esmarkii*), European sprat (*Sprattus sprattus*), Chilean jack mackerel (*Trachurus murphyi*) and chub mackerel (*Scomber japonicus*) (De Silva and Turchini, 2009). In Asia, fishmeal production is based on a mix of species typically derived from trawl fisheries and increasingly from seafood industry processing wastes. Although various feed ingredients of plant and animal origin are often used, whole and/or chopped trash fish/low-value fish remains the most widely used feed ingredient for feeding high-value, marine carnivorous fish throughout the Asia-Pacific region.

However, there is a marked difference among the global regions regarding the sourcing of fish-based protein for compound commercial and farm-made aquafeeds. The Asia-Pacific region is the largest consumer of feed fish, reduced or otherwise, as feed in aquaculture. Approximately 25 percent (9.8 million tonnes) of the total capture fishery production of 40 million tonnes in the Asia-Pacific region is currently used other than directly for human consumption (e.g. for fishmeal production or as animal/pet food). This contributes towards the production of 28 million tonnes of food fish for human consumption in the region (Funge-Smith, Lindebo and Staples, 2005; FAO, 2007). In 2003, over 9.9 million tonnes or 47.2 percent of the total fishery catch within the Americas region was destined for reduction and non-

[5] In 2004, FAO estimated that discarded global catch was approximately 7 million tonnes. Estimating the total amount of global bycatch is difficult for a variety of reasons. Depending on the definition used, bycatch may be in excess of 20 million tonnes (FAO, 2011).

food uses (Tacon, 2009), while the farming of mainly carnivorous species in Europe currently uses around 1.9 million tonnes of feed fish to meet fishmeal and fish oil requirements (Huntington, 2009). In Africa and the Near East, around 0.86 million tonnes of pelagic fish were reduced to fishmeal and fish oil in 2004–05 (Hecht and Jones, 2009).

The Asia-Pacific region also remains the main consumer of trash fish/low-value fish as direct fish feed. It has been estimated that Viet Nam uses nearly 900 000 tonnes of trash fish/low-value fish and that China would require approximately 4 million tonnes of trash fish/low-value fish by 2013 to sustain marine cage culture activities (De Silva and Hasan, 2007). The annual amount of fish used as direct aquaculture feed in the Asia-Pacific region in 2004 was in the range of 2.47 to 3.88 million tonnes (De Silva and Turchini, 2009). It has further been predicted that aquaculture would use between 9.23 and 13.97 tonnes of low-value fish by 2010, which would be equivalent to 33 to 50 percent of this global resource (De Silva and Turchini, 2009). It now needs to be ascertained whether this prediction was correct. Nevertheless, the above highlights the importance of trash fish/low-value fish as feed in Asian aquaculture. The availability of trash fish/low-value fish in Viet Nam is considered one of the most serious constraints for aquaculture development. Apparently, the most important fisheries that target low-value fish for aquaculture feed are, or were, in Viet Nam (Dao, Dang and Huynh Nguyen, 2005), yielding up to 0.6 million tonnes/year. In the Americas and Europe, the use of trash fish/low-value fish as a direct feed in aquaculture is negligible. In the Americas, it is currently restricted to the on-growing and fattening of tuna in Mexico using locally caught sardines, and total trash fish/low-value fish consumption was estimated to be about 70 000 tonnes in 2006 (Tacon, 2009). However, the volume of sardines and other pelagics used as baitfish by commercial and recreational fisheries within the region (primarily in Canada and the United States of America) is believed to be greater than that used by the aquaculture sector and is conservatively estimated to be about 100 000 tonnes per annum (Tacon, 2009). The absence of any substantive data suggests that the use of trash fish/low-value fish as direct feed in aquaculture in Africa and the Near East is negligible (Poynton, 2006; Hecht and Jones, 2009).

Although the majority of fishmeal/fish oil is derived from marine species, there is an emerging trend to use freshwater pelagics in aquafeeds. In Kenya, between 50 and 65 percent of the silver cyprinid (*Rastrineobola argentea*, local name: "dagaa", also known as "omena" in Uganda) catch from Lake Victoria is reduced to fishmeal (Abila, 2003). In 2004, the total recorded "dagaa" catch was 31 659 tonnes (FAO, 2006b), suggesting that 15 800 to 20 500 tonnes of fish was reduced to fishmeal. With growing popularity of

aquaculture in Africa, it can be expected that more fish will be used to supply the industry.

2.2 The issues

There is a growing concern that the use of fish as feed in aquaculture has more negative than positive implications for the poor, and that it is not ethically correct to use fish as feed if it can be used for human consumption. There are five main concerns regarding the use of fish as feed; these relate primarily to the supply of low-priced fish as food, income earning possibilities (Wijkström, 2009) and direct impacts on ecosystems and biodiversity:

- When fish is obtained from a reduction fishery and converted into fishmeal that is incorporated into feeds used to grow fish and/or shrimp, then less fish is available as human food – and particularly for the poor.
- When fish is obtained from the bycatch of commercial fisheries or from surplus landings of small pelagic fisheries and then fed to cultured fish either directly or as fishmeal, the quantities of low-priced fish normally accessible by the poor in port markets are reduced.
- The growing use of fishmeal in fish and other animal feed contributes to an increase in fishing pressure on reduction fisheries or direct targeting in non-selective trawl fisheries (Kristofersson and Anderson, 2006; Skewgar *et al.,* 2007). This may affect the sustainable use of some wild fish resources, and therefore eventually lead to less fish being available for human consumption, which will affect the poor in particular.
- When fish is obtained from a reduction fishery and converted into fishmeal, the on-shore job opportunities are lower than if the fish were destined for processing and direct human consumption. This affects the poor in particular, as much of the processing only requires low-skilled labour.
- Removal of large quantities of forage fish species from marine ecosystems affects other dependent piscivorous animal species, including other fish species, birds and mammals (Huntington *et al.*, 2004; Worm *et al.*, 2006; Skewgar *et al.*, 2007).
- The use of trash fish/low-value fish as feed in aquaculture raises the possibility of transmitting diseases/pathogens from non-endemic feed fish to local wild fish populations, as has been experienced in Australia (WWF, 2005).

Countering these concerns, the global fishmeal industry claims that there is no current demand for direct human consumption for up to 90 percent of the wild-caught fish that is reduced to fishmeal (FIN, 2004). From a global

perspective, this is probably correct. However, on a regional or individual country basis, there is evidence to suggest that a proportion of the reduction fishery catch is simply not available for human consumption (Abila, 2003), although if it had been available it would certainly have been consumed (Kurien, 1998). In Europe and North America, the reduction of fish has no direct consequences because of the low number of poor and undernourished people (Wijkström, 2009); and in Africa, reduction fisheries are an exception and aquaculture is nascent and not much dependent on fish as feed (Hecht and Jones, 2009). In the Americas, an increasing proportion of the marine fish catch is expected to be processed for direct human consumption, primarily in the form of easy-to-use and affordable processed fish products, including canned fish and stabilized surimi-based products (Tacon, 2009). In Asia, the situation is different. Unlike other aquaculture-producing regions, Asia is largely dependent on imported fishmeal and fish oil (mainly from South America and northwest Europe). The few industrial feed-fish fisheries that exist in Asia (mainly in China and Japan) have been declining (Huntington and Hasan, 2009). Manufacturers of fishmeal and fish oil have therefore had to make greater use of trawler bycatch and occasional surplus catches as raw material. The demand for trash fish/low-value fish is now also fuelled by the growth of small-scale rural aquaculture in Viet Nam, which has led to the development of a trash fish/low-value fish fishery that supplies the aquaculture sector. It is clear therefore that the use of trash fish/low-value fish has become a serious issue in certain regions, while in others it is a non-issue.

2.3 Sustainability of fish stocks

Irrespective of the region, fisheries that generate excessive bycatch and discards are ultimately not sustainable, especially where there are no management strategies for non-target species. Moreover, the removal of large numbers of forage fish from an ecosystem may directly affect their prey and predators and the viability of target and bycatch populations (Huntington and Hasan, 2009). Although most commercially exploited feed-fish stocks are capable of withstanding relatively large reductions in biomass (Daan *et al.*, 1990; Jennings, Kaiser and Reynolds, 2001), the removal of extremely high numbers of spawning stock may lead to recruitment overfishing. Pelagic species are particularly vulnerable to recruitment overfishing, as they are short-lived (Lluch-Belda *et al*., 1989; Santos, Borges and Groom, 2001).

The incidental catch of non-target species and, in particular, the capture of juveniles of commercial species, is one of the most controversial aspects of feed-fish fisheries, as most undersized fish are landed and processed, resulting in growth overfishing. For example, in North Atlantic waters, juvenile herring are known to shoal with sprat (Hopkins, 1986), while juveniles of

commercial species such as whiting (*Merlangus merlangus*) and haddock (*Melanogramus aeglefinus*) are known to shoal with Norway pout (Huse *et al.*, 2003). In tropical ecosystems, most fisheries are multispecies and although a few species have a higher value than others, a high percentage of the catch consists of "non-targeted species". On the other hand, the level of discards is very low given that most of the catch is used for human consumption, except for some fisheries such as the tropical shrimp fisheries, in which discard rates are high. Prohibition of landing of bycatch will undoubtedly affect the aquafeed manufacturers in countries such as China, Thailand and Viet Nam and will reduce the availability of this fish as a source of human food and feed for livestock in the rest of Asia. Also, prohibiting the use of bycatch in aquaculture feeds will not necessarily solve the management problem of those fisheries characterized by large volumes of bycatch. On the other hand, discarding of bycatch is irresponsible and unethical, as it affects livelihoods and removes a source of food for the poor, particularly in Asia. Therefore, once landed, all measures should be taken to make use of the bycatch to provide food for the poor and generate livelihoods.

2.4 Food security and livelihoods and low-value/bycatch fish

There is evidence that much of the trash fish/low-value fish, bycatch and some of the forage fish catch could be better used for human consumption, either directly (e.g. in Europe, species such as capelin, Atlantic herring and even blue whiting [*Micromesistius poutassou*] have potential for human consumption) or through some form of processing such as canning mainly for export (e.g. Peruvian anchovy and jack mackerel) or for local/regional use (e.g. in surimi production, by better on-board preservation, or as dried, salted or fermented products). In those regions where bycatch is landed, there exists an opportunity for the local poor and undernourished to obtain cheap fish, if it is offered for sale in wet-fish markets. However, when landed, the bycatch is typically damaged or is in a poor state of preservation and is often unfit for human consumption. The available data for Africa and the Near East show that 60 percent of the small-pelagic catch is used for human consumption and only 40 percent is reduced to fishmeal (Hecht and Jones, 2009). It would seem that in Asia most of the trash fish/low-value fish is largely inedible due to damage, poor preservation/icing or being undersized species and can only be used for fish and animal feeds (De Silva and Turchini, 2009). However, the potential to use trash fish/low-value fish for human consumption could be enhanced if it were properly sorted from the other bycatch and preserved for human consumption. This is already happening in some fisheries; in particular, the technology for surimi is developing and its price increasing. However, this would lead to an increase in the price of the fish, making it less affordable to those for whom it was intended in the first place (Wijkström, 2009).

On the other hand, there are cases where the use of feed fish provides employment opportunities and benefits in the form of income to ensure food security and livelihoods. One such example is the net benefit derived by employees in the South African abalone farming industry (Hecht and Jones, 2009, see Box 1 on p. 28 for details). Moreover, in Asia, there are thousands of artisanal fishers who cater directly to the needs of the aquaculture sector by providing trash fish/low-value fish (De Silva and Turchini, 2009). In 2004, the total aquaculture production that was dependent on fish as direct feed in Asia was estimated to be about 1.54 million tonnes (De Silva and Turchini, 2009), which may have generated direct employment of 0.27 million person-years (0.175 person-year/tonne of fish). In addition, the number of people employed in related activities (e.g. bringing fish to the farm, manufacture of feed, transporting the product to export markets) is estimated to be equal to the number of farm employees. Hence total employment generated would be in the order of 0.5 million person-years (Wijkström, 2009).

The opposing argument is that if the bycatch was not used in fish farming, it could, at best, have been used for the production of food. Such activities are labour-intensive. The employment generated in post-harvest activities averages 1.5 person-years per tonne of fish (landed weight), and this means that hypothetically between 8.1 and 10.2 million individuals, mostly unskilled, could have been employed by the fish processing industry for production of food. Even if a large degree of uncertainty surrounds these numbers, it seems clear that, in Asia, the utilization of bycatch as food (provided that the bycatch is preserved in a condition fit for human consumption) would generate more employment than using the fish as feed in aquaculture (Wijkström, 2009). However, the question remains as to whether the "processed" bycatch would still be affordable to the poor.

In summary, there is no single answer as to whether more feed fish should be made available for direct human consumption. There are clear regional differences, and all consequences – economic, social and environmental – of policy change must be considered to ensure that inappropriate solutions are not rushed through on the back of simplistic assertions (Huntington and Hasan, 2009). However, it is preferable and likely that some fisheries resources currently used for fishmeal or as fresh aquaculture feed may become more valuable as human food as economic and/or technological changes make it more viable to use this fish directly.

3. EXISTING GUIDELINES ON FISHERIES MANAGEMENT AND INITIATIVES TO IMPROVE SUSTAINABLE MANAGEMENT OF FISH STOCK RESOURCES

Over the past 50 years, humans have changed ecosystems more rapidly and extensively than in any comparable period of time in human history. These changes have contributed to substantial net gains in human well-being and economic development at growing costs in the form of the degradation of many ecosystem services. One of the ecosystem services reported as degraded in the Millennium Ecosystem Assessment is capture fisheries. World capture fisheries have reached a plateau at around 94 million tonnes, with at least half of the world's recognized fish stocks fully exploited and about 32 percent overexploited or depleted (FAO, 2005b, 2010e). Unless urgently addressed, these problems, coupled with undesirable fishing practices such as overfishing, illegal, unregistered and unreported fishing (IUU) and the use of destructive methods, will substantially diminish the benefits that future generations obtain from ecosystems (Millennium Ecosystem Assessment, 2005).

The FAO Code of Conduct for Responsible Fisheries (CCRF), adopted in 1995 (FAO, 1995), looks to ensure that the right to fish "carries with it the obligation to do so in a responsible manner so as to ensure effective conservation and management of living aquatic resources". The CCRF is now widely recognized by governments and non-governmental organizations (NGOs) as the global standard for setting out the aims of sustainable fisheries and aquaculture and as a basis for reviewing and revising national fisheries legislation (FAO, 2010b). The CCRF and all key international agreements adopted over the last two decades stress the need for the adoption of an ecosystem approach to fisheries (EAF). In response to these, in 2001, 57 countries issued the Reykjavik Declaration on Responsible Fisheries in the Marine Ecosystem, which included a declaration of their intention to work on incorporating ecosystem considerations into fisheries management. In general, the tools and techniques of the EAF will remain the same as those used in fisheries management, but they will need to be applied in a manner that addresses the wider interactions between fisheries and the whole ecosystem (FAO, 2010b).

3.1 Technical guidelines on fisheries management

The technical guidelines on fisheries management (FAO, 1997b) have been produced to support the implementation of Article 7 (Fisheries Management) of the CCRF, with some reference to Article 12 (Research). They are addressed primarily at the decision-makers within fisheries management authorities and other interest groups, including fishing companies, fishers organizations, concerned NGOs and other stakeholders.

The guidelines provide a background to the need for fisheries management and an introduction to the activities encompassed by fisheries management. They introduce the major constraints experienced in fisheries and fisheries management and some of the fundamental concepts related to them. Biological, environmental, technological, sociocultural and economic constraints and concepts are examined. Information is fundamental to responsible fisheries management, and these guidelines put emphasis on the range of data required for informed decision-making, and examine aspects of the collection and interpretation of these data. Data are discussed in terms of three suggested scales in fisheries management: fisheries policy and development planning, formulation of management plans, and implementation of management actions. Three main possible management options and approaches as outlined in the guidelines, viz., i) options to regulate fishing, ii) limit access and iii) co-management of resources, have been summarized in Annex 1.

The guidelines on the implementation of the EAF (FAO, 2003, 2005c) further highlight the sustainability principles enshrined in the CCRF and provide guidance on the steps required for implementation.

As seen in the previous section, there exist several sets of technical guidelines on the sustainable management of fisheries, as well as several continuing initiatives to improve sustainable management of fisheries, which *inter alia* would also apply to feed-fish fisheries. The intention of this document is to formulate guidelines on issues related to feed-fish fisheries management without repeating the technical guidelines that are already available.

4. PRINCIPLES AND TECHNICAL GUIDELINES ON THE USE OF WILD FISH AS FEED IN AQUACULTURE

The FAO Expert Workshop on the Use of Wild Fish and/or Other Aquatic Species as Feed in Aquaculture and its Implications to Food Security and Poverty Alleviation was convened in Kochi, India, from 16 to 18 November 2007. The workshop prepared an outline for technical guidelines on the "Use of wild fish as feed in aquaculture". The workshop concluded that the use of fish as feed is acceptable, but should be governed by a set of principles:

4.1 Principles governing the use of wild fish as feed in aquaculture

These technical guidelines are based on ten principles and encompass five key issues: a) fisheries management considerations, b) ecosystem and environmental impacts, c) ethical issues and responsible use, d) aquaculture technology and development, and e) statistics and information needs for management. These principles have been adapted from the Report of the Kochi Workshop (FAO, 2008).

4.1.1 Fisheries management considerations

Principle 1: Aquaculture should utilize resources from sustainably managed fisheries.

In the past decades, there has been an increasing awareness that sustainable stocks of wild fish are essential to secure the supply of raw material that the seafood industry relies on and are vital in maintaining volumes and quality, as well as stabilizing price. The future goal is to use feed fish from certified "responsibly managed" fisheries. It is important that aquaculture makes a progressive move towards sourcing feed fish exclusively from better managed and more sustainable fisheries. However, currently, the main buying criteria for fishmeal for inclusion in aquafeeds are price and quality. Beyond ensuring that fish are purchased from stocks that are managed within national and international laws and agreements, there has been little attempt to procure feed fish from "sustainable sources" and that change is needed to take this into account.

Guidelines under Principle 1

1.1. Where a reduction fishery/feed-fish fishery is not managed sustainably, the aquaculture sector, as a stakeholder, should insist that concrete action be taken to introduce measures that will achieve its sustainable

management (CCRF[6] Article 7.1.1[7], Article 7.2.1[8]) (see Annex 1: Technical Guidelines on Fisheries Management).

1.2. Consumers are encouraged to obtain products from those aquaculture producers who adopt responsible and sustainable practices.

1.3. Until feed-fish fisheries have been certified as being managed sustainably, fish-feed producers should be encouraged to develop buying criteria for fishmeal and fish oil based on sustainably managed fisheries.

1.4. Internationally (e.g. Marine Stewardship Council ecolabel certification) or regionally standardized certification criteria for sustainably managed feed-fish resources should be adopted, so that the feed industry has a clear direction to source fish from sustainable feed-fish and reduction fisheries. Where currently recognized certification schemes or criteria are not appropriate, others must be developed in consultation with all stakeholders.

1.5. While recognizing that the bulk of the catch from some fisheries is destined for reduction, the industry should be mindful to maximize the use of the products, where such demand exists, for direct human consumption.

Principle 2: Where wild aquatic organisms are harvested for use as feed, responsible fisheries management frameworks should be put in place and implemented (CCRF Article 9.1.4[9]).

This principle applies to the major reduction fisheries of the world, which are typically managed fisheries whose stocks are specifically targeted for use as

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[6] Code of Conduct for Responsible Fisheries (FAO, 1995).

[7] CCRF Article 7.1.1: States and all those engaged in fisheries management should, through an appropriate policy, legal and institutional framework, adopt measures for the long-term conservation and sustainable use of fisheries resources. Conservation and management measures, whether at local, national, subregional or regional levels, should be based on the best scientific evidence available and be designed to ensure the long-term sustainability of fishery resources at levels which promote the objective of their optimum utilization and maintain their availability for present and future generations; short-term considerations should not compromise these objectives.

[8] CCRF Article 7.2.1: Recognizing that long-term sustainable use of fisheries resources is the overriding objective of conservation and management, States and subregional or regional fisheries management organizations and arrangements should, *inter alia*, adopt appropriate measures, based on the best scientific evidence available, which are designed to maintain or restore stocks at levels capable of producing maximum sustainable yield, as qualified by relevant environmental and economic factors, including the special requirements of developing countries.

[9] CCRF Article 9.1.4: States should ensure that the livelihoods of local communities, and their access to fishing grounds, are not negatively affected by aquaculture developments.

feed. In other cases, feed fish are derived from fisheries that are not managed, i.e. where trash fish/low-value fish are directly targeted for use as feed, or where the fish is derived from the bycatch of targeted fisheries and landed for use as feed.

Technical guidelines for the management of reduction and feed-fish fisheries have been developed to address these issues (Annexes 1, 2, 3 and 4).

Guidelines under Principle 2

2.1. When evaluating existing or proposed operations producing fish for feed, the impact on the fish stock and the ecosystem must be assessed in terms of sustainability, habitat and social implications (see Annex 2).
2.2. Fish for feed should come from a managed fishery or be subject to a management arrangement (e.g. under a regional fisheries management organization [RFMO]). Fish for feed may come from fisheries outside national waters and therefore not be subject to a national fishery management plan. In these instances, steps should be taken to ensure responsible and sustainable fishing and to enforce conservation and management measures in compliance with international agreements (e.g. United Nations Convention on the Law of the Sea [UNCLOS], United Nations Fish Stocks Agreement [UNFSA]).
2.3. Where artisanal fisheries for feed fish are not under a comprehensive management regime, such fisheries should be the subject of local regulations to ensure their sustainability.
2.4. Where aquaculture operations are dependent upon fish for feed, research and development programmes that aim to reduce this dependence should be promoted.

4.1.2 Ecosystem and environmental impacts

Principle 3: Reduction fishery and directed feed-fish fishery operations should not significantly impact the environment or create significant negative ecosystem-level impacts, including impacts on biodiversity.

Small pelagic stocks are usually resilient to high exploitation levels, but their robustness can be compromised by wider climatic and other perturbations. Environmental concerns regarding the use of large volumes of bycatch include the possible wider biodiversity and ecological impacts resulting from the removal of such a large and diverse biomass. Due to the small size and low age of small pelagics, the stocks are difficult to manage on a multi-annual basis. While their high fecundity allows for rapid recovery, there is concern over the

impact of fishing pressure on predator-prey relationships in already stressed ecosystems. The increased dependence of the aquaculture sector on marine capture fisheries as a feed source is a matter of concern for their management.

Guidelines under Principle 3

3.1 Where the bycatch of a fishery forms a significant part of the catch, ecosystem-level impacts may include growth and recruitment overfishing of bycatch species. Where this occurs, specific management measures must be introduced for the bycatch component. Targets should be to minimize growth overfishing, to minimize catch of non-target species and juveniles, and to reduce discarding.

3.2 The fishing of fish for feed should not significantly affect biodiversity. In certain instances, there may be a need to formulate research on the effects of biomass removal from specific trophic levels on ecosystem functioning.

3.3 In the absence of specific management strategies, the precautionary approach should be adopted to safeguard feed-fish fisheries until the ecosystem linkages between feed-fish fisheries and natural predatory fish, sea birds and marine mammals are fully understood.

3.4 Fishing pressure should not be increased to harvest stocks or species that were not previously fished at commercial scale without establishing possible consequences for its main predators.

3.5 Where the monitoring of ecosystem impacts of reduction and feed-fish fisheries is not undertaken or does not use internationally accepted indicators, then such measures should be introduced.

3.6 Where growth overfishing in a feed-fish fishery is a significant threat to the target resources or bycatch, measures such as licensing of operations, mesh-size restrictions and elimination of harmful fishing gear and methods should be introduced.

4.1.3 Ethical issues and responsible use

Principle 4: Using fish as feed should not adversely impact the livelihoods and compromise food security of poor and vulnerable groups, especially those directly dependent upon the resource.

Supplies of trash fish/low-value fish are finite and, as indicated by recent price increases, demand is outstripping supply. It has been argued that it would be more efficient and ethical to divert more of the limited supply to human food by using value-added products, than to supply fishmeal plants for an export, income-oriented aquaculture industry producing high-value commodities. On

the other hand, food security can also be increased by improving the income-generation abilities of poor people; the basis of this statement is that the large number of people employed in both the fishing and aquaculture sectors contributes towards food security and poverty alleviation, which contributes more to sustainable livelihoods than only a supply of cheap fish. However, an increasing demand for particular fish resources by the fish-feed industry may have a negative impact on food security. Clearly, where such imbalances exist, they need to be addressed by governments and aquaculture and fish-feed manufacturing industries so that the distribution of the resources is equitable and does not have a detrimental effect on basic nutritional needs of local communities. Therefore, understanding the negative social impacts stemming from the use of fish for feed is necessary. It is recognized that there are inevitable trade-offs relating to resource allocation. Therefore, in the application of the principles on such practices, care should be taken to mitigate negative social and economic impacts.

Guidelines under Principle 4

4.1 In the regions where there is a recognized impact of reduction or feed-fish fisheries on food security, improved efficiency in the supply chain should be promoted so that more fish is available for human consumption instead of it all being reduced to fishmeal.

4.2 The fish-feed manufacturing industry should explore opportunities for substitution of food-grade fish with other feed ingredients, including animal by-products and seafood industry processing waste, and the use of nutritional supplements to maintain feed quality.

4.3 Small-scale fish farmers should be encouraged to move away from using trash fish/low-value fish as a feed source to formulated feed, thereby increasing the availability of fish for human consumption.

4.4 A regional effort that brings together researchers, feed manufacturers, raw-material suppliers and farming communities should be initiated to develop diets with lower fishmeal/fish oil content.

4.5 Regional approaches should be initiated to develop ways and means of improving the efficacy of farm-made/ semi-commercial feeds and disseminating appropriate strategies for their improvement, thereby reducing the amount of trash fish/low-value fish used directly in feeds or as fishmeal.

4.6 Public/private partnership research should be encouraged and initiated to address issues related to the high oil content of pelagics, with the specific aim of facilitating diversification of small pelagic fish products, especially for direct human consumption.

4.7 While using the feed-fish catches to develop products for human consumption, the focus should be to target markets in poorer inland areas.

4.8 The comparative benefits of producing fishmeal for use in different types of aquaculture industries versus the socio-economic benefits of harvesting the fish directly for human consumption should be investigated (Box 1).

Box 1
Costs and benefits of reduction fisheries: an example from the South African abalone farming industry

Hecht and Jones (2009) examined the comparative benefits of producing fishmeal for use in the rapidly expanding South African abalone farming industry versus the socio-economic benefits of harvesting the fish directly for human consumption. Although abalone (*Haliotis midae*) are herbivorous, the industry is partly dependent on a fishmeal-based artificial diet and will become more so as it grows and as ocean-harvested kelp becomes limiting (Troell *et al.*, 2006). The abalone culture industry in South Africa used approximately 320 tonnes of artificial feed in 2005 (Jones and Britz, 2006), which equates to about 96 tonnes of fishmeal. The fishmeal reduction yield that is accepted as an industry standard in South Africa is 23 percent, meaning that about 420 tonnes of live fish were reduced to produce the 96 tonnes of fishmeal for the abalone culture industry. The minimum daily protein requirement for a person is 1.38 g dry protein/kg (Scrimshaw, 1996). Assuming that the average employee supports a family of four with a total average weight of 180 kg (i.e. a minimum daily dry protein requirement of 248 g/family) and that the protein content of fresh fish is 16 percent (Miles and Jacob, 2003), then it is possible to estimate that the fish that was reduced to fishmeal to feed the abalone culture industry would have sustained about 741 families for a year had they utilized the fish directly. However, the abalone culture industry employed 814 people in 2004 (Troell *et al.*, 2006), who used their salaries to purchase substantially more than their protein requirement. This example suggests that the "secondary" use of reduction fishery products is able to sustain more families indirectly than it would have sustained directly. However, *would the community have been better-off selling it for human consumption?* Had the fishmeal not been reduced and had the farm workers retained their fishing rights, the catch would have realized US$1.5 million, i.e. US$1 778/worker per year, before fishing expenses are taken into account. If it is assumed that abalone farm workers earn the minimum wage for South African farm labourers (i.e. ZAR871.58/

Box 1 (Continued)

month, 2004), they would have earned an annual net salary of US$1 687/ worker. From this it was concluded that the reduction fishery has not placed the abalone farm workers at an economic disadvantage.

At the same time, the costs of some reduction or feed-fish fisheries in the developing world probably outweigh the benefits, as the production of the "secondary product" does not always result in employment, leaving the poorest of the poor worse-off and without access to protein or monetary income. Therefore, further investigation is required to seek ways in which to reduce the social conflict between potential users of the resource, where this exists.

Principle 5: The use of fish as feed should not be governed by market forces alone.

While recognizing that food insecurity and poor nutrition are social problems that need to be addressed broadly and with more fundamental measures, appropriate market intervention to enable equitable access to fish resources – whether food fish or feed fish – by the poor will contribute to promoting their food security.

The market generally favours the use of feed fish for reduction or for direct use in aquaculture. In Southeast and East Asia, where the proportion of bycatch is high (adding to the reasons that the poor have diminishing access to cheap fish), this is abetted by poor technology and practices that render fish, particularly bycatch, unfit for the food market. Investments in better technology for on-board quality preservation would maintain the quality of food-grade bycatch so that it can be sold as food fish. As food-grade fish, bycatch is expected to fetch a higher price than as an input to fishmeal production. As an effective short-term measure, appropriate incentives (subsidy) for fishers to invest in such technology can encourage its adoption.

It is also technically feasible to treat feed-fish species as food fish and market them to the poor. For economic (e.g. unattractive margin for producers and sellers) and probably cultural reasons (e.g. low preference for the species), this is seldom done on a significant scale. As a result, no dramatic change over the medium term is foreseen in the proportion of feed-fish species being used directly as food. However, for a number of feed-fish species that are

acceptable as food (e.g. herring, sardines, anchovy), there has been a slow but noticeable increase in the quantities used as food. Similarly, some species previously considered to be of low value as food are now targeted to produce surimi. The factors that influence their demand by the poor include their affordability and the poor's preference for them. Another influence on the amount of feed fish that can be allocated for the food market is the price of other protein commodities, particularly soybean; a lower price is expected to lessen the demand for fishmeal for feed manufacture.

Guidelines under Principle 5

5.1 Policies that regulate the market need to be developed and implemented to ensure that the harvest, allocation and use of feed-fish resources do not diminish food security.

5.2 On the supply side, market-based incentives should be developed to overcome the barriers to the allocation and marketing of feed fish for food that the poor can afford.

5.3 On the demand side, measures to stimulate demand for low-cost fish resources as food should be implemented to provide the opportunity for feed-fish fishers to supply a greater percentage of the catch for direct human consumption.[10]

5.4 In situations where value-addition may reduce the availability of fish to the poor[11], States should adopt policies to make fish available in wet and value-added forms that are affordable to poor people.

5.5 National governments should seek ways in which to improve access by the poor and malnourished to food-grade feed fish for direct consumption.

Principle 6: Formulation of policies related to the use of fish as feed should not exclude other users of this primary resource.

To date, governments have not effectively limited the practice of using fish as feed in order to safeguard a supply of cheap fish – either by limiting the use of small pelagic fish for the production of fishmeal and fish oil or by

[10] It has been estimated that reallocation of 157 300 tonnes or 1.8 percent of the Peruvian anchovy catch from the reduction fishery to human consumption would be sufficient to raise the Peruvian annual consumption from 21 to 25 kg per capita (Sanchez Durand and Gallo Seminario, 2009). The demand has first to be created, however.

[11] Examples exist from Kenya and Morocco, where fish protein that was affordable to the poor in the past is no longer available because of "value-adding". Clearly, where such imbalances exist, they should be addressed by states and fishing industry such that the distribution of the resources is equitable and does not have a detrimental effect on basic nutritional needs of local communities.

restricting the use of bycatch as animal feed and thereby increasing the supply of cheap fish as food. This may be due to greater focus on creating employment rather than looking after the immediate food requirements of the poor. It has been shown that employment is the best way to alleviate poverty, which in turn leads to improved nutritional status because of the resultant higher purchasing power. However, policies should be balanced to ensure employment opportunities as well as to enhance the availability of fish affordable for poor people.

Guidelines under Principle 6

6.1 National governments and international agencies should initiate a dialogue with resource users to develop policies and the application of economic measures and regulations that build awareness and consensus that leads towards equitable and ethical resource allocation.

6.2 States should promote the use of existing feed-grade waste streams within the fisheries sector, including discarded fisheries bycatch and fishery processing wastes, as feed in aquaculture.

6.3 States should encourage commercial and sports/recreational fisheries to replace food-grade bait species with farmed bait species and/or artificial baits developed from feed-grade fish processing waste.

6.4 Given the importance of increasing the availability of fish for human consumption for both food and nutritional security, States should adopt a policy to invest in on-shore based infrastructure development to facilitate sorting, separating and preserving low-value fish from other bycatch fish for human consumption.[12]

6.5 States should consider measures to support the increased use of feed-fish species as human food. Such measures could include incentives for the sale of certain species[13] as food or regulation that permits their use as raw material for reduction only after it is demonstrated that the food market demand has been satisfied.

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[12] In some regions (e.g. Asia, Africa), trash fish/bycatch is largely inedible and can only be used for fish and animal feeds. Even if edible, the value of the fish is too low for it to be transported into more inland areas for direct consumption. However, there are opportunities for switching low-cost fish towards direct human consumption, most likely through some form of processing (e.g. as a protein mix or a dried, salted or fermented product like fish sauce). However, the potential is limited due to the difficulties in sorting and separating low-value fish from other bycatch and preserving it for subsequent direct consumption.

[13] Prominent species in this category include: Chilean jack mackerel, Peruvian anchoveta, North Atlantic herring, blue whiting and capelin. The prime example is the EU's regulation for North Atlantic herring, which must be offered for sale as food, and is only permitted as raw material for reduction once the food market has been satisfied.

6.6 Fishing companies, processors and fishmeal and fish-oil manufacturers should develop codes of conduct and/or BMPs, such that their corporate activities are recognized as being responsible and sustainable.

4.1.4 Aquaculture technology and development

Principle 7: Aquaculture should be encouraged to make a progressive move away from using wet fish as feed to formulated/compound feeds.

Formulated/compound feeds (which include industrially produced pellets and farm-made aquafeeds) are preferable to the use of wet fish as feed, as they increase the flexibility of raw material options and allow for additional control over such characteristics as product consistency, nutritional quality, transport volume, stability and hygiene. Therefore, the use of formulated feeds should lead to improved environmental performance and enhanced overall efficiency at the farm level. It is recognized that the use of formulated feeds may not be appropriate in all circumstances, especially in locations with poor infrastructure or where wet-fish supplies are available from sustainable fisheries. Thus, this issue should be treated on a case-by-case basis using cost-benefit analyses that incorporate environmental and social parameters, where possible.

Guidelines under Principle 7

7.1 Policies to promote the development and use of complete formulated feeds to gradually replace the direct use of trash fish/low-value fish should be supported by following one or more development initiatives, such as:

a) grassroots-level extension and training programmes to educate and encourage fish farmers to use formulated feeds;
b) preferential financial and loan/credit support to farmers to change from trash fish/low-value fish to formulated feeds;
c) mechanisms to discourage irresponsible use of trash fish/low-value fish, especially those practices that cause pollution or other damage to the environment;
d) priority species and key technological areas for public-sector support for research and development;
e) guidance, support and coordination services to research institutions and the feed manufacturing industry for artificial feed development;
f) incentives to local fishmeal producers to produce high-quality fishmeal from low-value but high-yielding fish species.

7.2 Consideration should be given to the production of alternative aquafeed resources, e.g. polychaetes, algae, *Artemia*, molluscs, etc.

7.3 Where appropriate, local fishmeal and aquafeed manufacturing sectors should be developed and promoted to address specific local needs and to improve access to formulated feeds, as this will provide additional livelihood opportunities to local populations.

7.4 Feed manufacturers and suppliers have a responsibility to provide appropriate quality feeds and to assist farmers in managing and presenting these feeds on-farm in ways that facilitate efficient and optimal uptake by the stock[14] (CCRF Article 9.4.3[15]).

7.5 Feed manufacturers and suppliers should be held responsible to declare the source and type of all raw materials used in feed manufacture and the final nutritional composition.

7.6 As capacity building is required to promote the adoption of new feed technologies, aquafeed manufacture and the use of alternative raw material, education, extension, demonstration and training should be implemented.

7.7 In regions where it is needed, measures should be taken to improve the quality of fishmeal by improving reduction techniques, avoiding the inclusion of foreign material and contaminants.

7.8 Converting low-grade, land-animal by-products into high-value aquafeed protein with the appropriate amino acid balance should be investigated, as it may be an innovative way to reduce fishmeal inclusion rates in aquafeeds.

7.9 Concerted and well-planned genetic research should be undertaken at the national as well as the regional level to improve feed utilization by aquaculture species.

7.10 Concerted and well-planned research at the national as well as the regional level should be undertaken to document the seasonal availability of feed ingredients and their nutritional profiles as alternate protein sources to fishmeal and fish oil, and such information should be made accessible to the fish feed producers, irrespective of scale.

7.11 Dissemination of information to the farmers and others in aquaculture sector regarding the benefits of using formulated feeds (e.g. improved digestibility, better nutritional balance, lower environmental impact) should be improved.

7.12 The use of whole fish or ground trash fish with low feed conversion ratios (FCRs), poor digestibility and high wastage should be avoided to prevent water quality problems.

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[14] FAO Technical Guidelines for Responsible Fisheries No. 5, Aquaculture development (page 29): Selection and use of feeds and additives (FAO, 1997).

[15] CCRF Article 9.4.3: States should promote efforts which improve selection and use of appropriate feeds, feed additives and fertilizers, including manures.

7.13 In cases where formulated industrial feed is not an option due to economic reasons, farm-made compound dry feeds should be promoted for both semi-intensive and intensive aquaculture. In such cases, farm-made/semi-commercial feeds should be developed under suitable environmental conditions and necessary steps taken to enhance conversion efficiencies by reducing the direct impacts from their non-digestible components.

7.14 Success stories on environmental best practices from one region should be disseminated to others and replicated.

7.15 Innovative approaches should be adopted in the search for new protein sources, e.g. microbial and plankton products, bacteria, microalgae, protists and yeasts.[16]

Principle 8: The use of fish as feed should not compromise food safety and quality of aquaculture products.

Use of environmentally contaminated fishmeal and fish oil within aquafeeds may have a consequent potential risk of transferring contaminants to the cultured species and eventually to the consumer (Hites *et al.*, 2004a, 2004b; Foran *et al.*, 2005), either by concentration of pollutants through the food chain or via the production and distribution process.

Moreover, trash fish/low-value fish used as feed could be a source of parasites that may threaten human health. Certain pathogens (e.g. *Salmonella*) derived from raw materials or feed ingredients may also colonize and persist in feed manufacturing facilities and could be transmitted to aquaculture ponds/cages. In addition, the use of highly perishable trash-fish-based feed has in some instances resulted in increased environmental pollution (Tacon *et al*., 1991; Ottolenghi *et al.*, 2004). This in turn may lead to increased biosecurity and disease risks (Gill, 2000; SCAHAW, 2003; Hardy, 2004; Anon, 2005).

Guidelines under Principle 8

8.1 The use of fish for feed should not present a risk of disease and contaminant transfer from wild fish to the aquaculture stock. In case of risk of disease and contaminant transfer, necessary measures should be adopted to prevent/reduce such risks.

[16] Plankton (including copepods, euphausiids, amphipods and krill) that feed in low trophic levels contain bioactive compounds like omega-3, bound phospholipids and axastanthin and have the potential to serve as a source of protein, oil, attractants and pigments. However, exploitation of plankton should strike a balance to avoid negative consequences to organisms at higher trophic levels.

8.2 The use of environmentally contaminated fishmeal and fish oils in aquafeeds should be avoided to prevent consequent potential risk of transferring contaminants to the cultured species, the environment and the end consumer. The quality and freshness of raw aquatic materials should be maintained at all stages in the supply chain.

8.3 As persistent contaminants may be concentrated in feed fish, monitoring and control should ensure that levels are minimized in the finished feed and final products, in accordance with internationally recognized standards, to ensure that food safety and product quality are maintained.

8.4 Random samples of raw material (trash fish/low-value fish) should be tested for known contaminants by fishmeal and fish-oil producers, particularly when longer-lived and more fatty pelagic species are used, as the majority of these contaminants are fat soluble and tend to bio-accumulate within the fatty tissues of such species.

8.5 Small-scale fishmeal and fish-oil producers without access or capacity for such testing should provide an assurance that the raw material used in fishmeal and fish oil production is from a known and contaminant-free source.

8.6 Fishmeal and fish-oil manufacturers should use raw material (trash fish/low-value fish) that does not contain unsafe levels of biological, chemical or physical contaminants. Use of raw material from known contaminated sources should be avoided and managed through appropriate traceability protocols (e.g. HACCP).

8.7 Feasible processing technologies to reduce contaminants to acceptable levels should be adopted and improved. Manufacturers should adopt good hygienic practices to prevent transmission of pathogens derived from raw material or ingredients through feeds. Wild trash fish may be treated (e.g. freezing/heating) to inactivate parasites.

8.8 Regulations on screening standards of fishmeal should be enforced to ensure the quality and safety of fishmeal used by feed manufacturers. A penalty for disposing of substandard fishmeal at lower price should be imposed.[17]

8.9 In addition to encouraging the use of properly formulated feeds to minimize the risk of accumulation of organic and inorganic contaminants in farmed stocks, regulations on the permitted levels of such contaminants in farmed fish should be introduced where these do not exist.

[17] When regulations on screening standards of fishmeal are enforced, there is a probability that substandard fishmeal will be sold at lower prices and could be acquired for farm-made feed production by farmers and small-scale feed manufacturers.

Principle 9: The use of alternative raw materials (of both animal and plant origin) should not compromise food safety and the quality of aquaculture products.

Significant progress has been made to reduce the dependence on fishmeal and fish oil through substitution with proteins and oils of terrestrial origin. However, the presence of dioxins, polychlorinated biphenols (PCBs) and other persistent organic pollutant (POP) residues in human food products of animal origin is a potential problem that has recently become particularly important. The increasing demand to include alternate protein ingredients of plant or animal origin into aquafeeds could have negative impacts due to the presence of antinutritional/toxic factors and/or biological hazards and contaminants if these are not carefully controlled.

Guidelines under Principle 9

9.1 For biosecurity reasons, intraspecies recycling is an unacceptable practice that should be prohibited.

9.2 If cultured raw materials are incorporated into aquafeeds, then specific care should be taken to ensure that antibiotic residues are not incorporated into the final feed.

9.3 Where they do not exist, regulations should be introduced and enforced to prevent import or export of banned animal industry by-products to be used in feeds. Banned by-products should be publicized among feed manufacturers and users and the avoidance of specified products should be included in BMPs.

9.4 As plant antinutritional factors may compromise growth and suppress the immune response of fish, plant material should be processed to mitigate the effects of antinutritional factors before inclusion as ingredients in fish feeds.

9.5 Use of raw materials from alternative sources must not transfer risk[18] to fish and to human health.

9.6 Awareness of the risks associated with the diversification of raw materials utilized for aquafeeds should be increased. It is important to develop and standardize risk assessment methodologies as well as

[18] Presence of dioxin (polychlorinated dibenzo-para dioxins [PCDDs] and polychlorinated dibenzofurans [PCDFs], dioxin-like PCBs) and other environmental contaminants in feed ingredients of aquatic origin, endogenous antinutritional and adventitious toxic factors in plant ingredients, transmissible spongiform encephalopathies (TSEs, also known as prion diseases that may lead to Creutzfeld Jacob disease) in rendered animal products (e.g. meat meal, bone meal, meat and bone meal) and risk of transfer of avian influenza or bird flu and other zoonotic agents from poultry by-products.

establish monitoring and control procedures for the management of alternative raw material use.

9.7 Appropriate regulations should be implemented to prevent adulteration of fish and animal feed ingredients or feeds with toxic chemicals, such as melamine and other substances, used fraudulently to inflate protein or nutritive content.

9.8 Appropriate regulations should be developed and implemented to screen feed ingredients of plant origin such as oilseeds and corn for aflatoxins.[19]

9.9 Feed manufacturers, irrespective of scale of operation, should be provided with guidelines for the storage and transport of feed ingredients and feeds, in particular regarding temperature, humidity and moisture levels.[20]

9.10 Screening regulations for bacterial contamination of feed ingredients of plant and animal origin should be implemented.[21]

9.11 Appropriate communication strategies should be developed, aimed at informing final consumers about the benefits and risks of fish fed on alternative materials.

9.12 Feed manufacturers should adhere to "Guidelines for good aquaculture feed manufacturing practice" (FAO, 2001) to avoid or minimize the negative impacts on food safety and the quality of aquaculture products that may result from the use of alternative raw materials to replace the use of fish in feeds.[22]

9.13 The effects of using alternate land-based protein sources to replace fishmeal on the nutritional quality of finishing diets such as omega-3 fatty acid levels and on the fatty acid profile and gustatory quality of the

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[19] A group of extremely heat-stable mycotoxins, produced by strains of *Aspergillus flavus* and *A. parasiticus*, that exhibit fluorescence on ultra-violet (UV) radiation. Feedstuffs, that are particularly prone to infestation by *A. flavus* are groundnuts, cotton seed and copra (FAO Glossary of Aquaculture, available at: www.fao.org/fi/glossary/aquaculture/).

[20] The production of aflatoxins increases at temperatures above 27 °C and humidity levels higher than 62 percent, and moisture levels in the feed above 14 percent. For the main aquaculture-producing regions of the world (notably Asia), these climatic factors increase the risk for such contamination.

[21] Compared with fungi, bacterial contamination is frequently overlooked but can have serious implication for fish and human health. Feed ingredients and feed contaminated with bacteria pathogenic to humans can contribute to human foodborne illness through the feed–animal–food–human chain. Bacterial contamination of feed ingredients or diets with potential pathogens such as *Salmonella, Escherichia coli, Staphylococcus, Streptococcus, Pasteurella, Pseudomonas* and *Clostridia* will compromise fish and human health.

[22] The use of alternative raw materials as ingredients to replace use of fish in feeds without compromising food safety and the quality of aquaculture products is reflected in the guidelines for good aquaculture feed manufacturing practice (FAO, 2001).

fillets should be evaluated. Consumers are increasingly interested in the health benefits of omega-3 fatty acids derived from fish.[23]

4.1.5 Statistics and information needs for management

Principle 10: Management of reduction and feed-fish fisheries or those with high levels of bycatch, which is used directly or indirectly as feed fish, requires sound biological, ecological and environmental data, as well as supply and value chain information and a participatory decision-making process that includes all stakeholders (fishery operators, traders, aquafeed and aquaculture producer associations).

The sustainability of fisheries used to provide feeds for farmed fish has become a key concern for the entire aquaculture supply chain. The marine protein component of feeds represents the direct link between capture fisheries and aquaculture. In many instances, historical trends in the catch and catch composition, catch per unit effort (CPUE), fish quality and economic value of the fisheries that produce fish for feed are not recorded or are poorly recorded. This is particularly the case for mixed-assemblage, multigear fisheries where there is non-selective targeting. Larger demersal and pelagic fisheries are generally better understood, managed and monitored.

Guidelines under Principle 10

10.1 Activities should be introduced to record trends in the catch and composition, CPUE, catch quality and economic value of fisheries that produce fish for feed, particularly for mixed-assemblage, multigear fisheries.

10.2 Where available, records of long-term catch and economic trends of capture fisheries that produce fish as feed should be maintained to allow for more effective decision-making concerning the trade-off between using the catch as feed or as food.

10.3 Where bycatch/trash fish/low-value fish is used directly as feed, records of the type and quantity of fish used by the aquaculture sector should be maintained.

[23] One of the important areas related to consumer health that should be addressed with regard to utilization of plant products in aquafeeds is omega-3 fatty acid level in fish fillets. Because the fatty acid composition of fish fillets is related to the fatty acid composition of the diet, fish fed primarily plant-based diets contain lower levels of omega-3 fatty acids.

10.4 To ensure that fishmeal and fish oil used in feeds are from sustainable fisheries, it is necessary to identify and adopt measures to address the specific constraints that hinder full traceability.[24]

10.5 Where possible, specific sustainability indicators should be developed for those fisheries that produce fish for feed (see Annex 4).[25]

10.6 Initiatives should be developed to collate available information to facilitate the development of regional and national sustainability indicators based on the framework suggested in the FAO guidelines on indicators for sustainable development of marine capture fisheries (FAO, 1999). Because indicators are not static and change with time, this collation should be in the form of a database that is renewed and updated regularly.

10.7 Relevant information on feed-fish fleets should be collected and analysed, such as the number of vessels or units, gear characteristics and selectivity, seasonality of fishing activities, locality of fishing to develop and facilitate enforcement of appropriate input control measures.[26]

10.8 FAO Member Countries should be encouraged to improve their reporting of the fisheries catch for non-direct human consumption and direct human consumption and start to provide this information as an annually updated data set. In addition to the importance of using this information for good fisheries management, such information is important to suggest any trade-offs of fish catch between non-direct human consumption and direct human consumption.

10.9 Information to determine the demand for trash fish/low-value fish for direct human consumption should be generated, including their suitability for consumption and opportunities for value addition. Such information is vital to ensure equitable access and to develop management measures for these resources.

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[24] Price and quality are the main buying criteria of fishmeal for inclusion in aquafeeds. One of the constraints in promoting the purchase of fishmeal made from sustainable resources or from stocks managed within national and international laws and agreements is traceability. Even though traceability is high on the feed industry's agenda, there is a lack of information to establish traceability due to difficulties in ensuring the origin of all fishmeal. For example, fishmeal can be blended during loading of tankers (both ship and road) and hence cannot be traced beyond that point.

[25] The role of indicators and reference points is fundamental to any fisheries management system. Existing fisheries management guidelines suggest that sustainability indicators should, in principle, cover stressors on the ecosystem, state of selected ecosystem components, and responses to the measures taken. The development of such indicators and reference points requires detailed and long-term time- and space-data series.

[26] Input control measures are easier and less costly to monitor and enforce than output control measures, particularly in multispecies fisheries.

10.10 To facilitate traceability, FAO Member Countries should be encouraged to record and report national fishmeal and fish-oil production statistics according to source (i.e. dedicated fishery, bycatch, trimmings, spoilt food fish, overproduction, etc.).

10.11 Awareness among stakeholders in the aquaculture supply chain of the importance of using raw materials from sustainably managed fish stocks as a means to maintain price stability in the provision of high-quality aquaculture products should be raised.

10.12 Government agencies should generate and disseminate relevant research information to retailers and processors that emphasizes the importance of operating at certain minimum levels of environmental responsibility. This should further be encouraged through adoption of formal industry codes of conduct and also through relevant informal criteria that may be set by NGOs, consumers and the media. The codes and criteria should be closely linked to concepts of "corporate reputation/responsibility" (see Annexes 5 and 6).[27]

[27] Retailers and processors are the most consumer-facing element of the aquaculture supply chain and are the focus of campaigns around seafood sustainability. Consequently, retailers have frequently played a leading role in developing sustainable seafood initiatives, and this trend is continuing with the issue of sustainable aquaculture feeds.

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ANNEX 1

Technical guidelines on fisheries management

The following is a summary of three main possible management options and approaches of the technical guidelines on fisheries management (FAO, 1997b) for multispecies/multigear feed-fish fisheries. These are: i) options to regulate fishing, ii) limit access, and iii) manage resources in partnership.

Options to regulate fishing
Technical measures to regulate fishing, such as a) gear restrictions to affect the type, characteristics and operation of a fishing gear or to regulate the mesh-size in order to be species specific; b) area and time restrictions to protect a component of a stock or community such as spawning adults or juvenile stages or to reduce or eliminate conflict between different components of the fishery system (e.g. artisanal, industrial and foreign fleets) or between them and other users; and c) declaration of marine protected areas to preserve spawner biomass above a threshold necessary to ensure sustained recruitment and critical habitats or sensitive life stages of species, were recommended. It is emphasized that technical measures such as gear restrictions and area and time restrictions should be used as part of an overall strategy developed in consultation with the interest groups, as they may lead to economic inefficiency and distortions, and may effectively reduce catch per unit effort (CPUE) below otherwise attainable levels.

Input (effort) control measures to regulate fishing are those that restrict the number of fishing units through limiting the number of licences or permits issued, restrictions on the amount of time units can spend fishing, such as individual effort quotas, and restrictions on the size of vessels and/or gear. Output control measures to regulate fishing are more suitable for large-scale fisheries, which include setting a total allowable catch (TAC) and subdividing it into individual quotas by fishing nation (in the case of international fisheries), fleet, fishing company or fishers (e.g. in the case of individual quotas).

Problems associated with determining the actual amount of effort by each fishing unit make it very difficult to regulate fisheries on input controls alone. Differences in the nature of the gear and technical aids used, quality of maintenance of vessel and gear, skipper skills and strategies contribute to this difficulty. In theory, catch control eliminates the need, for control purposes, of estimating the fishing efficiency of all units in the fishery and of monitoring and responding to changes in fishing efficiency with time, which are features of effort control. On the other hand, in the absence of limited

entry and individual quotas, catch control does not reduce the social and economic distortions brought about by competing fishers racing to obtain the greatest possible share of the TAC before it is filled. It also encounters problems associated with close monitoring of outputs per user and in total, to ensure the TAC and individual quotas are not exceeded, which calls for a comprehensive, accurate and costly monitoring system. Moreover, TACs and individual quotas are usually set and issued for single stocks and, in multispecies fisheries, this leads to the problem of discards and high-grading, as TACs and quotas for co-occurring species will be filled at differing rates.

Monitoring of fishing efficiency and the number of fishing units in the fishery are vital components to facilitate adjustment of the overall fleet capacity to take into account technological improvements. Without such adjustments, unregulated increases in capacity will increase the incentives for excess fishing and misreporting. Therefore, effort control may also be desirable to avoid the problems of excess capacity, even where output controls are in place. In theory, if sufficient data are available, it is possible to determine the relative efficiency of each vessel and fleet by comparing historical catches per unit of effort in a fleet data base. In practice, however, scarcity of data and continual change, often associated with efficiency increases, make such calibrations difficult.

The guidelines also emphasize the types of data are required for target stocks and their environments, characteristic of their fishery, and social and economic information to formulate policies and management plans and to determine management action and monitoring performance.

Limit access

Limiting access in fisheries is difficult and must consider various and cross-cutting issues and problems associated, among others, with open-access fisheries, overexploited fishery resources, declining returns in small-scale artisanal fisheries and industrial fisheries, competition to fish leading to shortened fishing seasons, poor product quality and sporadic availability, excess harvesting and processing capacity, and increased costs and related negative social and economic effects. The guidelines therefore include the following approaches to limiting access:

- Allocation of an access right to a community, individual or company, or a vessel by the state, regional or local authority.
- Granting of access on the basis of specific criteria, including, for example, a proven history of participation in the fishery and performance (e.g. catch above certain minimum criteria, a history of responsible fishing, of social responsibility, etc.).

One of the problems in switching from open access to limited access is in determining which of the previous users should be granted access and which should be denied access. Two approaches have been suggested, viz., a lottery system, which avoids possible problems of favouritism or unfair decisions, or to sell or auction the access rights. However, the lottery system does not ensure the continuance by the most responsible and effective users, and the latter system favours the wealthy. Where economic efficiency is the primary goal of the fishery and where considerations of equity are not an issue, the latter may be an appropriate approach. The guidelines emphasize the importance of ensuring equity in allocating rights. This requires that all current fishers be involved in the process and particular attention should be given to those with long-standing traditions of fishing, especially, where appropriate, to indigenous people and to those local communities that are highly dependent on fisheries for their livelihoods (Article 7.6.6).

Manage resources in partnership

Management of resources in partnership or fisheries co-management is to promote responsible fisheries management by accommodating the interests of a wide range of parties (who often represent competing or even conflicting interests) with various arrangements that formally recognize the sharing of fisheries management responsibility and accountability between a fisheries management authority and relevant other stakeholders. The extent to which the self-management responsibilities are delegated to implement management in partnership should be based on both the characteristics of the fishery concerned and the capacity of the decentralized or local institutions to handle the authority delegated as well as the capacity of the fisheries management authority to provide assistance, including administrative support, to the delegated partners. Management of resources in partnership is more suited particularly to small-scale fisheries. However, fisheries co-management may not be adopted in every fishing community.

Some of the constraints to develop fisheries co-management are:

i) communities may not be willing or able to take on the responsibility of co-management;
ii) there may be a lack of leadership and appropriate local institutions, such as fisher organizations, to initiate or sustain co-management efforts;
iii) the incentives (economic, social and/or political) to engage in co-management may not be present;
iv) the costs for individuals to participate in co-management strategies (time, money) may outweigh the expected benefits; and
v) sufficient political will may not exist to support co-management, and particular local resource characteristics, such as fish migratory patterns,

may make it difficult or impossible for the community to manage the resource.

Finally, the guidelines examine the management process. This covers the process of agreeing on a management plan for a fishery, including the need for consultation and, where appropriate, cooperative decision-making. A management plan is a formal or informal arrangement between a fishery management authority and interested parties that identifies the partners in the fishery and their respective roles, details the agreed objectives for the fishery and specifies the management rules and regulations which apply to it, and provides other details about the fishery that are relevant to the task of the management authority. Management plans drawn up for all fisheries will serve as a reference and information source for the management authority and all interest groups, summarizing the current state of knowledge on the resource, its environment and the fishery, and reflecting all the decisions and actions agreed upon during the course of consultations between the management authority and the interest groups. Ensuring plans are developed and implemented for all fisheries helps to avoid planned management measures on one fishery creating unforeseen problems and externalities in a neighbouring fishery for which no plan is available. The need for periodic review of management plans is stressed. The importance of an effective legal framework, institutional and administrative structures, and monitoring control and surveillance are described.

ANNEX 2

Technical guidelines on the ecosystem approach to fisheries

Management of target species through current fisheries management measures such as effort, catch, technical gear, access and area-based controls is not adequate to ensure sustainable development of fishery resources. Current fisheries management measures must be broadened to address a wider range of issues related to ecosystem health and integrity. The Code of Conduct for Responsible Fisheries (CCRF) and many international agreements have been adopted, and conferences over the past three decades (Box 1) have highlighted the benefits of adopting an ecosystem approach to fisheries (EAF) management and have elaborated a number of principles and concepts relating to the EAF. The FAO International Plans of Action aiming at conservation and management of sharks and a reduction of incidental catch of seabirds will also contribute to the implementation of an EAF (Garcia *et al*., 2003). The World Summit on Sustainable Development (WSSD) Plan of Implementation (WSSD-POI) requires, *inter alia*, the development and implementation of an ecosystem approach by 2012, together with: (a) the elimination of destructive fishing practices; (b) the establishment of marine protected areas (MPAs) and other time/area closures for the protection of nursery grounds; (c) the adoption of coastal land-use and watershed planning; and (d) the integration of economic sectors into marine and coastal area management (Garcia and Cochrane, 2005).

Box 1
International agreements and conferences highlighting the benefits of adopting the ecosystem approach to fisheries (EAF)

- The 1971 RAMSAR Convention on Wetlands
- The 1972 World Conference on Human Environment
- The 1973 CITES Convention on International Trade in Endangered Species of Wild Fauna and Flora
- The 1979 Bonn Convention on Migratory Species of Wild Animals
- The 1982 United Nations Convention on Law of the Sea (UNCLOS)
- The 1992 United Nations Conference on Environment and Development (UNCED) and its Agenda 21
- The 1992 Convention on Biological Diversity
- The 1995 United Nations Fish Stocks Agreement
- The 1995 FAO Code of Conduct for Responsible Fisheries
- The 2001 Reykjavik Declaration
- The 2002 World Summit on Sustainable Development (WSSD)

The FAO technical guidelines on the EAF (FAO, 2003) have attempted to translate the higher-level principles into operational objectives and measures capable of delivering on the EAF in a broad range of social and economic settings, particularly in developing countries. The guidelines also recognize that there is a need to improve current fisheries management by taking into consideration the interactions that occur between fisheries and ecosystems, and the fact that both are affected by natural long-term variability as well as by other, non-fishery uses.

The most specific issues in the EAF relate to the impact of fisheries on the environment (including biodiversity and habitat) and the impact of the environment on fisheries (including natural variability and climate change). EAF management, therefore, takes into account the interactions between fisheries and ecosystems and includes a broader range of users of marine ecosystems (including both extractive and non-extractive users) in decision-making, through participatory processes. Most importantly, the approach aims to ensure that future generations will benefit from the full range of goods and services that ecosystems can provide by dealing with issues in a much more holistic way, rather than by focusing on only certain target species or species groups, as has often been the case until now. The technical guidelines (FAO 2003) define the EAF as follows:

> "An ecosystem approach to fisheries strives to balance diverse societal objectives, by taking into account the knowledge and uncertainties about biotic, abiotic and human components of ecosystems and their interactions and applying an integrated approach to fisheries within ecologically meaningful boundaries".

These guidelines attempt to make the EAF operational by recognizing that this approach is a way to implement many of the provisions of the CCRF and achieve sustainable development in a fisheries context. They provide guidance on:

- how to translate the economic, social and ecological policy goals and aspirations of sustainable development into operational objectives;
- indicators and performance measures; and
- how to extend and broaden current fisheries management practices to take account of the biotic, abiotic and human components of ecosystems in which fisheries operate.

Ecosystem impacts of fisheries relate, *inter alia*, to target stocks (e.g. abundance, productivity, size and species composition), non-target species (e.g. endangered species, bycatch, discards), and critical habitats and other

anthropogenic impacts on fisheries (as well as on product quality), and originate mostly from activities on land and in the coastal area. EAF management guidelines provide several options to manage fisheries, taking the above impacts into consideration. They are: i) technical measures, ii) input (effort) and output (catch) control measures, iii) ecosystem manipulation measures, and iv) rights-based management measures. Technical measures include gear modifications to improve selectivity, which includes size selectivity of target as well as non-target species, other gear issues, spatial and temporal controls of fishing, control of the impact from fishing gear on habitats, and energy efficiency and pollution. Input (effort) and output (catch) control measures include controlling overall fishing mortality and catch controls. Ecosystem manipulation includes prevention of habitat modifications, providing additional habitats, and population manipulation, which involves restocking and stock enhancement, culling and intentional introductions.

Technical measures

Gear modifications to improve selectivity: EAF management recognizes the ecosystem effects due to change in trophic structure by discarding bycatch on target as well as non-target species and genotypic and phenotypic changes in fish populations, such as changes in growth and in size and age at first maturity that may occur due to size-selective harvesting. Guidance includes size selectivity of gear for target as well as non-target species.

Other gear issues: Passive gear such as gillnets and traps/pots can have a negative impact by continuing to capture fish in cases where the gear is lost (ghost fishing). To minimize this negative impact, measures such as the use of biodegradable material in gear and quick recovery are included.

Spatial and temporal controls on fishing: Closure or restricting fishing to certain times or seasons can be effective in controlling or managing fishing mortality. One form of closure can be the declaration of MPAs, ranging from "no take" to planned "multiple-use" areas. MPAs can protect sedentary species, allow a proportion of the stock to remain free of the selective effects of fishing, and may act as refuges for the accumulation of spawning biomass from which replenishment of surrounding fished areas can occur, either through out-migration of fish or dispersal of juveniles.

Control of the impact from fishing gear on habitats: A precautionary approach is recommended on the use of high-impact fishing methods, such as demersal fishing gear that touches or scrapes the bottom during fishing operations, and which are likely to have a negative impact on the biota and the abiotic habitat, particularly where this is a critical habitat. Use of towed gear with reduced

bottom contact, prohibition of certain gear in critical habitats (e.g. trawling in coral reef and seagrass areas), and replacement of high-impact fishing methods with others that have a lower impact on the bottom (e.g. trapping, longlining or gillnetting) are recommended.

Energy efficiency and pollution: Modern fishing vessels that use fossil fuels need to optimize energy use through improved gear and fishing effort efficiency to reduce greenhouse gas emissions.

Input and output control measures
Controlling overall fishing mortality: Capacity controls on the total size of the fleet have the potential to reduce fishing mortality on entire species complexes in exactly the same manner as effort or spatial/temporal access limitations. Effort limitations to restrict the fishing activity of fleets can reduce fishing mortality. In current fisheries practices, the main limitations of any of these controls are that they do not directly constrain the fleet from targeting and depleting an individual stock. From an EAF viewpoint, these input controls have the virtue of restricting the overall pressure on the ecosystem, thus offering the potential of limiting negative impacts, as there is a considerable danger that fishing mortality will steadily increase if increasing efficiency is not monitored and controlled. Some technological progress such as development of echo-sounders and satellite navigation may enable fishers to direct more of their effort towards the target species and thus diminish the impact on non-target species.

Catch controls: Catch controls in the form of catch limitations on target as well as non-target bycatch species are aimed at reducing fishing mortality on target species and protecting associated species. It will be necessary to implement a set of consistent catch limits across the range of target and bycatch species to reflect these differences and address desired ecosystem-related objectives (such as maintaining food webs). Catch limits for target species may need to be modified to control catches of more vulnerable species.

Ecosystem manipulation measures
Habitat modification: Habitat preservation in marine fisheries is key to the EAF, because it underpins the health of exploited ecosystems. The different measures needed to reduce such impacts include:

- prohibition of destructive fishing methods in ecologically sensitive habitats (such as seagrass beds);
- prohibition of intentional cleaning of the seafloor to facilitate fishing; and
- reduction of the intensity of fishing in some fishing grounds to ensure that non-target, habitat-forming species are not reduced below acceptable levels.

In situations where insufficient habitat is available to support certain species of concern, additional habitat can be created by re-establishing lost or damaged habitats such as mangroves, sea grass beds, coral reefs and/or constructing artificial habitats.

Population manipulation: Population manipulations can be achieved either by restocking and stock enhancement, culling or intentional introductions. Restocking involves releasing cultured juveniles of target species that have been heavily overexploited to rebuild the spawning biomass, and then protecting the released animals, the remnant wild stock and the progeny until the population increases to the desired level. In general, restocking should be considered only when other forms of management are incapable of restoring populations to acceptable levels, and it should be coupled with controlled fishing capacity and reduced overfishing. Restocking programmes must incorporate: (i) hatchery procedures that prevent loss of genetic diversity by guarding against inbreeding and selective breeding; and (ii) quarantine protocols that prevent the transfer of pathogens from cultured animals to the wild. Stock enhancement may be carried out to overcome recruitment limitation and to increase the yields of a target species. The same hatchery procedures should be observed as in the case of restocking. There are several cost/benefit factors to be considered in stock enhancement programmes. These are:

- the need to minimize production of hatchery-reared juveniles by optimizing the scope for natural replenishment by wild stocks;
- the abundance of predators and prey at proposed release sites; and
- the need for independent assessments to determine whether the enhancement programme is achieving its goals and whether it is having adverse effects on the ecosystem. It may also be necessary to provide additional habitat to support the increased numbers of enhanced species.

Culling is used to reduce the abundance of predators or species that compete for the same trophic resources, in order to increase the yields of target species or to maintain the balance of the trophic structure. This has to be carried out with caution to ensure that it produces only the desired effect and does not result in unwanted changes in abundance of other important components of the ecosystem or threaten the survival of the species culled. Consideration should first be given to the rebuilding of target species populations through other, more conventional, fisheries management measures. Large-scale culling should be conducted only after the full implications of the manipulation have been thoroughly investigated.

Intentional introduction of species is carried out to create a new fishery. A precautionary approach is needed in intentional introductions as there is a high risk of causing detrimental changes in the ecosystem(s). Some introductions of marine species have resulted in social and economic benefits with no apparent impacts on other components of the ecosystem. Fisheries for *Trochus* in the Pacific and scallops in China are good examples. A comprehensive risk assessment should be undertaken before considering the creation of new fisheries based on introduced species so as to understand the benefits and consequences of such measures.

Rights-based management approaches

In order to overcome the ecological consequences of allowing open access to fisheries, a well-defined and appropriate system of access rights in a fishery can bring many essential benefits. An important benefit of granting access rights to fish, that match the productivity of the resource, is that it provides fishers or fishing communities with longer-term security and enables and encourages them to view fishery resources as an asset to be conserved and treated responsibly. There are different types of access rights. Territorial use rights in fisheries (TURFs) (assigning of rights to fish to individuals or groups in certain localities) allows limited entry to a number of individuals or vessels to take part in a fishery within a certain zone or area, with entry being granted by way of a licence or other form of permit. TURFs in fisheries can remove, to a greater or lesser extent, the condition of common property.

Alternatively, entry may be regulated through a system of effort rights (input rights) or by setting catch controls (output rights), where the total allowable catch (TAC) is split into quotas and the quotas allocated to authorized users. Each type of user right has its own properties, advantages and disadvantages. Given that the ecological, social, economic and political environment varies from place to place and fishery to fishery, it stands to reason that no single system of user rights will work under all circumstances.

EAF technical guidelines also suggest actions that facilitate implementation of management measures. The following actions are listed:

- Improve the institutional framework (definition of rights and participatory processes).
- Develop collective values (education, information, training).
- Create non-market economic incentives (taxes and subsidies).
- Establish market incentives (ecolabelling and tradable property/access rights, as discussed above).

The guidelines also emphasize the problems facing fisheries management in an EAF which are outside the direct control of fisheries managers. Examples of such problems include:

- eutrophication of coastal waters resulting from excess nutrients from agriculture and sewage, which cause toxic algal blooms and affect the health of sea grass and coral reef habitats (by encouraging growth of epiphytes, for example);
- sediment loads from agriculture, forestry and construction of infrastructure in catchment that degrade coastal ecosystems, particularly, critical coral reefs and seagrass habitats;
- destruction of fish habitats through foreshore development;
- introduction of exotic species through ballast water and on the hulls of ships;
- contamination of fish products through chemical pollution from agriculture and industry;
- competing use of waterways from other sectors, including aquaculture; and
- effects of climate change on distribution of stocks and sea level rise on nursery habitats.

Fisheries managers need to ensure that they are recognized as important stakeholders in the process of integrated coastal management so that they can safeguard the function of the habitats that support fisheries ecosystems from adverse effects stemming from activities in other sectors.

The guidelines outline the development of an EAF management plan which involves: i) social and institutional issues; ii) descriptions of fishing activities, resources and the ecosystem, ecological issues and challenges; iii) agreed management measures to regulate fishing; iv) pre-agreed decision rules; v) nature of access rights; vi) evaluation of status of stocks; vii) arrangements for monitoring, control and surveillance; viii) communication strategy; and ix) nature of reviewing and auditing of performance of management.

From a global perspective, the EAF is still in its very first stages of implementation, although it may already be quite advanced in a number of countries. It represents the only opportunity for fisheries to become responsible and sustainable, but its implementation involves many challenges for the stakeholders (Garcia and Cochrane, 2005), such as:

- Policy-makers need to:
  - improve the image of fisheries governance;
  - identify the main operational objectives;
  - allocate resources through appropriate systems of rights;

  - identify the proper set of stakeholders and resolve the thorny issue of exclusion in an equitable manner;
  - maintain capture fisheries production while reducing environmental impact; and
  - lobby to reduce coastal pollution and degradation.
- Scientists need to:
  - identify effective and feasible measures;
  - advise on boundaries that make both ecological and institutional sense;
  - elaborate a conceptual equivalent to maximum sustainable yield for ecosystems (Hall, 1999; Murawski, 2000);
  - identify a parsimonious set of ecosystem indicators and associated reference values;
  - credibly assess ecological risks;
  - develop rehabilitation strategies;
  - elaborate affordable transition pathways;
  - integrate social sciences; and
  - communicate with fishers.
- Industry needs to:
  - actively change the image of the industry;
  - face the challenge of capacity reduction;
  - adopt more environment-friendly gear and practices; and
  - lobby for fishing rights.

Moreover, the EAF increases the implementation of existing fisheries management guidelines. A levy (or a tax on products) could be imposed in commercial fisheries in exchange for the right to fish (which is the existing case in many instances), but this would not seem appropriate for many small-scale fisheries, and costs may be reduced through devolution of responsibilities and co-management, self-management, and mobilization of social pressure to improve compliance. However this may require additional costs to improve local implementation capacity, coordination and control (Garcia and Cochrane, 2005).

ANNEX 3

Precautionary approach

The precautionary approach to fisheries management is about being cautious when scientific knowledge is uncertain, and not using the absence of adequate scientific information as a reason to postpone action or failure to take action to avoid serious harm to fish stocks or their ecosystem.

A precautionary approach is therefore a set of agreed measures and actions, including future courses of action, that ensures prudent foresight and reduces or avoids risk to the resource, the environment and the people, to the best extent possible, taking into account existing uncertainties and the potential consequences of being wrong (FAO, 1996). FAO technical guidelines on the precautionary approach to fisheries management include precautionary measures for four typical situations: i) new or developing fisheries; ii) overutilized fisheries; iii) fully utilized fisheries; and iv) traditional or artisanal fisheries (FAO, 1996) (Box 1). Some of these will apply to all types of fisheries, whereas others will be useful only in specific situations such as overexploited fisheries. The measures could be included in comprehensive fisheries plans and can also be used in the interim plan for immediate precautionary action until various proposed management plans been evaluated and approved to replace the interim action.

Box 1
Precautionary approach measures

New or developing fisheries

- Always control access to the fishery early, before problems appear. An open-access fishery is not precautionary. Immediately put a conservative cap (or default level) on both fishing capacity and the total fishing mortality rate. This could be achieved by limiting effort or total allowable catch.
- Build in flexibility so that it is feasible to phase vessels out of the fleet, if this becomes necessary. To avoid new investments in fishing capacity, temporarily license vessels from another fishery.
- To limit risks to the resource and the environment, use area closures. Closures provide refuges for fish stocks, protect habitat and provide areas for comparison with fished areas.

Box 1. (Continued)

- Establish precautionary, preliminary biological limit reference points (e.g. spawning stock biomass less than 50 percent of the initial biomass) in the planning stage.
  - Encourage fishing in a responsible manner to ensure long-term persistence of a productive stock or other parts of the ecosystem.
  - Encourage development of fisheries that are economically viable without long-term subsidies.
  - Establish a data collection and reporting system for new fisheries early in their development.
  - Immediately start a research programme on the stock and fisheries, including the response of individual vessels to regulations.
  - Take advantage of any opportunities for setting up experimental situations to generate information on the resources.

Overutilized fisheries

- Immediately limit access to the fishery and put a cap on a further increase in fishing capacity and fishing mortality rate.
- Establish a recovery plan that will rebuild the stock over a specific time period with reasonable certainty.
- Reduce fishing mortality rates long enough to allow rebuilding of the spawning stock.
- When there is a good year class, give priority to using the recruits to rebuild the stock rather than increasing the allowable harvest.
- Reduce fishing capacity to avoid recurrence of overutilization.
- Alternatively, allow vessels to move from an overutilized fishery into another fishery, as long as the pressure from this redeployment does not jeopardize the fishery that the vessels are moving into.
- Do not use artificial propagation as a substitute for the precautionary measures listed above.
- In the management plan, establish biological reference points to define recovery, using measures of stock status, such as spawning stock biomass, spatial distribution, age structure, or recruitment.
- For species where it is possible, closely monitor the productivity and total area of required habitat to provide another indicator of when management action is needed.

Fully utilized fisheries

- Ensure that there are means to effectively keep fishing mortality rate and fishing capacity at the existing level.

Box 1. (Continued)

- There are many "early-warning signs" that a stock is becoming overutilized (e.g. age structure of the spawners shifting to an unusually high proportion of young fish, shrinking spatial distribution of the stock or species composition in the catch). These warning signs should trigger investigative action according to prespecified procedures while interim management actions are taken, as noted below.
- When precautionary or limit reference points are approached closely, prespecified measures should be taken immediately to ensure that they will not be exceeded.
  - If limit reference points are exceeded, recovery plans should be implemented immediately to restore the stock. The recommendations for overutilized stocks described above should then be implemented.
  - To prevent excessive reduction of the reproductive capacity of a population, avoid harvesting immature fish unless there is strong protection of the spawning stock.

Traditional or artisanal fisheries

- Keep some areas closed to fishing in order to limit risks to the resource and the environment.
- Delegate some of the decision-making, especially area closures and entry limitations, to local communities or cooperatives.
- Ensure that fishing pressure from other (e.g. industrial) segments of the fishery does not deplete the resources to the point where severe corrective action is needed.
- Investigate the factors that influence the behaviour of harvesters to develop approaches that can control fishing intensity.

Source: FAO (1996).

ANNEX 4

Initiatives to improve sustainable management of fish stock resources

Concerns over the sustainability of fish stock resources originally focused on capture fisheries intended for consumption, but this focus has now broadened to other wild fish stocks and to aquaculture. There are several initiatives throughout the supply chain, including:

- the development of sustainability certification standards that will incorporate criteria for the sustainability of food-fish and feed-fish fisheries;
- the development of business-to-business systems to give assurance as to the quality of fishmeal and fish oil, including sustainability of fish stocks;
- the emergence of individual policies by retailers, including the direct prohibition of fishmeal and oil from certain fisheries; and
- a renewed enthusiasm among campaign groups to engage on the issue (SFP, 2009).

Development of sustainability criteria/indicators

Any certification standards to certify a fish resource as sustainable should be guided by a set of well-defined criteria and indicators to measure the sustainability of the stock. The criteria or indicators to determine the sustainability of specific reduction fisheries based on variations in reported landings, stock biomass fishing capacity and effort, and on the existence and implementation of adequate fisheries management regimes (Yndestad and Stene, 2002; SEAFEEDS, 2003; Bjørndal *et al*., 2004) give little or no consideration to wider ecosystem implications such as trophic interactions, habitat destruction and potential social, economic and environmental benefits and risks (Parsons, 2005).

The role of indicators and reference points is as fundamental to an ecosystems approach to fisheries (EAF) management as it is to conventional fisheries management and to any assessment of sustainability of fisheries. FAO has produced technical guidelines on developing indicators for sustainable development of marine capture fisheries (FAO, 1999) that outline the process to be followed at the national or at regional levels to establish a Sustainable Development Reference System (SDRS) and indicators. The guidelines were produced in support of implementation of the Code of Conduct for Responsible Fisheries (CCRF, particularly Article 7 (Fisheries Management) but also Articles 6 (General Principles), 8 (Fishing Operations), 10 (Integration of Fisheries into Coastal Area Management), 11 (Post-harvest Practices and Trade) and 12 (Research), and cover all dimensions of sustainability

(ecological, economic, social and institutional), as well as key aspects of the socio-economic environment in which fisheries operate (Tacon, 2009). These guidelines are aimed mainly at the decision-makers and policy-makers in marine capture fisheries, but are also useful to fishing companies and fisheries associations, non-governmental organizations (NGOs) with an interest in sustainable development and fisheries and other groups concerned with fisheries resources. They are complementary to the Guidelines on Fisheries Management but provide the broader perspective needed for a sectoral and holistic approach to sustainability in fisheries.

The guidelines include a simple framework for indicator development based on the indicators framework of the United Nations Commission on Sustainable Development (CSD) and various scales relating to geographical area (Box 1).

Marine Stewardship Council (MSC)

In February 1996, the World Wide Fund for Nature (WWF) and Unilever formed a partnership with the goal of creating economic incentives for sustainable fishing through the establishment of an independent, non-profit Marine Stewardship Council (MSC). The mission of the MSC (www.msc.org/) is to safeguard the world's seafood supply by promoting the best environmental choice, and it works to enhance responsible management of seafood resources to ensure the sustainability of global fish stocks and the health of the marine ecosystem. The MSC houses and oversees a programme whereby fisheries conforming to a set of predetermined criteria for sustainable fishing are eligible for certification by independent, MSC-accredited certifying firms (Tacon, 2009). In the selection of criteria for "sustainable fishing" the most widely accepted generic model is the principles and criteria for "responsible fishing" developed by the MSC (Huntington and Hasan, 2009). The MSC principles and criteria consider whether a fishery is sustainable depending upon a demonstration of:

- the maintenance and re-establishment of healthy populations of targeted species;
- the maintenance of the integrity of ecosystems;
- the development and maintenance of effective fisheries management systems, taking into account all relevant biological, technological, economic, social, environmental and commercial aspects; and
- compliance with relevant local and national laws and standards and international understandings and agreements (Huntington and Hasan, 2009).

Products from fisheries certified to MSC standards are permitted to carry an on-pack logo, providing consumers with the choice of selecting seafood products that come from sustainably managed sources (Tacon, 2009).

Box 1
Framework for indicator development

	Scale			
Dimension	**Global**	**Regional**	**National**	**Local**
Economic				
Social				
Ecological				
Institutional/ Governance				

Source: FAO (1999).

Huntington (2004) took the basic MSC criteria and adapted them to specifically suit feed-fish fisheries, applying them to the five main fisheries that provide the bulk of fishmeal destined for the fish farming industry in Scotland (United Kingdom). For each indicator, there are three "scoring guideposts" that assist assessors in determining the score out of 100. For instance, there are guideposts for what passes at 60, 80 and the ideal score of 100.

Huntington and Hasan (2009) highlighted the following advantages and limitations of the MSC approach:

- It responds well to fisheries and ecosystem issues. Nevertheless, it does not provide a specific assessment of the economic or social elements.
- It provides a vigorous quantitative approach to assess the main elements upon which to ensure that the fishery is sustainable.
- It is not clear whether it can be successfully applied to feed-fish fisheries, whose main species constitute an important forage prey, unlike many of the top predators that have been the focus of many fisheries certification schemes to date.
- It does look at implications of target species removal on ecosystem structure and function, but it has been a challenge to determine and quantify the effects in practice.

Those members of the aquaculture supply chain with an interest in defining sustainability standards for feed have been enthusiastic about the potential for sourcing fishmeal and fish oil from MSC-certified fisheries but, until

recently, there have been few feed-fish fisheries that have attempted certification or met the required standards (SFP, 2009). Currently, the only MSC-certified fisheries used for fishmeal and fish oil are North Sea herring (388 000 tonnes in 2007 – 2.4 percent of the total global catch destined for fishmeal and fish oil) and Norwegian spring spawning herring (1 267 000 tonnes in 2007 – 7.8 percent of the total global catch destined for fishmeal and fish oil). Consequently, only slightly more than 10 percent of the total catch used for fishmeal and fish oil is MSC certified. It is unlikely that very large volumes of fishmeal and fish oil from MSC-certified fisheries will be available in the short term, although there are causes for longer-term optimism.

With growing interest in ensuring the sustainability of aquaculture products throughout the production chain, the certification of feed-fish stocks has become an urgent priority – indeed this has become a priority with the MSC, which has launched a partnership with the Soil Association to develop certified sustainable sources of fishmeal and fish oil for organic farmed fish diets (Fishupdate.com, April 2006). Denmark has the largest fishmeal and fish-oil fisheries in the European Union and has pledged to have all fisheries MSC certified before the end of 2012, and it was announced that the giant Peruvian anchovy fishery (5.8 million tonnes in 2007 – 35.6 percent of the total global catch destined for fishmeal and fish oil) will go into the pre-assessment phase of MSC certification (SFP, 2009). Given the demanding nature of the standard, it may be some time before the fishery becomes certified; but if certification ever happens, it will ensure very large volumes of sustainable fishmeal and fish oil will become available.

International Fishmeal and Fish Oil Organization (IFFO)

IFFO is the international, non-profit organization that represents fishmeal and fish-oil producers and related trades throughout the world. The IFFO has almost 200 members in approximately 40 countries and represents nearly two-thirds of world production plus around 80 percent of exports of fishmeal and fish oil worldwide (www.iffo.net). In May 2008, the IFFO announced that it was producing a Code of Responsible Practice for Fishmeal and Fish Oil. The code will be a business to business certification scheme that will ensure, among other things, that compliant fishmeal and fish-oil products have been derived from fisheries that meet the key elements of the FAO Code of Conduct for Responsible Fisheries and that all national laws relating to fishing are complied with. Compliance will be established via third-party audit based on a desk study (SFP, 2009). Fisheries already certified by the MSC will automatically be considered as compliant in terms of sustainability. The creation of the code has been guided by a technical advisory committee that includes a range of

stakeholders such as fishmeal and fish-oil producers, traders, processors, feed manufacturers, retailers and environmental NGOs. Information about the operational status of the code is not yet available.

Fishmeal Information Network (FIN) initiative
The Fishmeal Information Network (FIN) is an information resource and a source of contacts for fishmeal, its supply chain and its role in the nutrition of farm livestock. The FIN aims to present fact-based information, independent evidence and respected expert opinion on fishmeal and its use. The FIN (www.fin.org.uk) is an initiative of the international Grain and Feed Trade Association (GAFTA), which represents more than 800 suppliers of fishmeal, other animal feed ingredients, grain, pulses and rice in more than 80 countries. The GAFTA aims to promote international trade and to protect the interests of its members and has been a driving force since 1971, when it was established as a result of a merger between the London Corn Trade Association and Cattle Food Trade Association.

The FIN's key activities are:
- to provide a source of information and a point of contact for the industry as a whole;
- to supply comprehensive factual information relating to fishmeal, addressing concerns and highlighting the positive benefits of its use as a feed ingredient;
- to monitor and effectively communicate industry attitudes to fishmeal and the effect specification changes could have on its use;
- to safeguard the livestock producers' option to use fishmeal under the relevant safety and quality assurance schemes or within the production criteria specified by individual purchasers;
- to ensure regulatory decisions on feed taken at the United Kingdom and European Union (EU) level do not discriminate unfairly or without justification against fishmeal; and
- to provide practical advice to livestock producers about fishmeal and its use as a feed ingredient.

International Council for the Exploration of Sea (ICES)
The ICES (www.ices.dk) is an independent scientific organization advising The North Sea and North East Atlantic governments on the status and management of commercial fish stocks. The information collected by the ICES is developed into unbiased, non-political advice about the marine ecosystem.

In Europe, most work on northern stocks is through the ICES, which includes a number of relevant working groups:

- Planning Group for Herring Surveys;
- Planning Group on Northeast Atlantic Pelagic Ecosystem Surveys;
- Regional Ecosystem Study Group for the North Sea;
- Study Group on Assessment Methods Applicable to Assessment of Norwegian Spring Spawning Herring and Blue Whiting Stock;
- Study Group on Regional Scale Ecology of Small Pelagics;
- Study Group on the Estimation of Spawning Stock Biomass of Sardine and Anchovy;
- Working Group on Ecosystem Effects of Fishing Activities;
- Working Group on Northern Pelagic and Blue Whiting Fisheries; and
- Working Group on the Assessment of Mackerel, Horse Mackerel, Sardine and Anchovy.

These working groups feed information into the decision–making process through the ICES Advisory Committee on Fishery Management (ACFM). The ACFM meets twice a year (summer and late autumn) to prepare its advice, which is then translated into operative fisheries management measures by national governments and the EU. EU fisheries management in the Mediterranean tends to be focused upon coastal fisheries. In general, EU catch limits or quotas are not applicable in the Mediterranean, with the exception of limits on bluefin tuna that have been introduced in response to recommendations by the International Commission on Conservation of Atlantic Tuna (ICCAT).

General Fisheries Commission for the Mediterranean (GFCM)
The work of the General Fisheries Commission for the Mediterranean (GFCM) has focused on shared or straddling stocks, particularly those involving demersal and large pelagic species. The GFCM's Sub-Committee on Stock Assessment (SCSA) recently assessed the stocks of 11 small pelagic species, which will result in the development of management programmes controlling the pelagic trawling and purse seine fisheries exploiting European anchovy (*Engraulis encrasicolus*), sardine (*Sardina pilchardus*) and sprat (*Sprattus sprattus*) (FAO, 2006a).

The EU has produced a strategy and action plan to improve scientific advice and research in stock evaluation in the waters of non-EU coastal states. This will combine actions to: (i) improve data collection, management and use; (ii) increase the level of research, especially into ecosystem considerations; (iii) strengthen the role of regional fisheries organizations (RFOs); and (iv) provide greater cooperation with European research and advisory organizations, as well as improve the capacity of national fisheries administrations to operate within a regional context.

Ultimately, pressure for improved management of feed-fish stocks must come from both the aquaculture industry and from consumers. One of the barriers to the environmental certification of aquaculture in Europe has been the ability to be assured of the sustainability of fishmeal and fish oils in compound feeds. As mentioned above, this has become an increasingly important issue, with feed manufacturers looking to the FIN or reassurance. There has also been growing pressure for independent certification through such schemes as the MSC's standard for responsible fishing.

ANNEX 5

Initiatives to develop sustainability standards for aquaculture feeds

The increasing attention on sustainable fish resources has also been manifest in the engagement around feed criteria for the development of aquaculture certification standards and non-governmental organization (NGO) campaign activity around the management of some of the fisheries that supply fishmeal and fish oil. There have also been individual initiatives by some retailers and processors to set and maintain specific sustainability standards for aquaculture feed.

World Wide Fund for Nature (WWF) Aquaculture Dialogues and the Aquaculture Stewardship Council

WWF, a conservation NGO (www.wwf.org), is instrumental in bringing together different stakeholders such as scientists, aquaculturalists, processors, retailers, feed manufacturers and environmental NGOs to develop a common set of criteria for the certification of sustainable culture for 12 different species (shrimp, salmon, abalone, clams, mussels, scallops, oysters, pangasius, tilapia, trout, yellowtail king fish [*Seriola*] and cobia). The work on tilapia, pangasius, abalone and bivalves (mussels, clams, scallops and oysters) has been completed, while the standards for salmon, trout and shrimp are available in draft form. Work on *Seriola* and cobia has just been initiated. The WWF is also creating the Aquaculture Stewardship Council, which is expected to be operational in 2011, and which will work with third-party bodies to certify aquaculture farms against the developed standards.

Global Aquaculture Alliance

The Global Aquaculture Alliance (GAA), an international, non-profit trade association dedicated to advancing environmentally and socially responsible aquaculture, has a set of certification standards for shrimp farms and hatcheries, tilapia and channel catfish farms, and seafood processing plants. There is some awareness of feed sustainability issues (e.g. in the tilapia standard there is a requirement that "Farms shall accurately monitor feed inputs and minimize the use of fishmeal and fish oil derived from wild fisheries" and there is an intention that "Fishery based ingredients from wild sources should come from sustainable fisheries"). However, it is not clear how the sustainability of the source fisheries would be measured. The GAA currently has draft guidelines for a best aquaculture practice concerning feed mills that states: "Feed mills shall not source fishmeal and fish oil from fish stocks for which the International Council for the Exploration of the Sea (www.ices.dk), Food and Agriculture Organization

(FAO) of the United Nations or the Sustainable Fisheries Partnership (SFP, www.sustainablefish.org) have reported a recommendation of no fishing, unsustainable harvesting, closed fisheries or overexploitation, or identified as a stock in a critical condition. Products from illegal, underreported and unregulated fishing shall also be avoided. Instead, aquafeed producers should actively favour marine oils and proteins derived from fisheries that are classified by reputable international third parties, such as the FAO, Marine Stewardship Council or SFP, as sustainably fished, fully fished or underexploited. In addition, to bolster sustainable sourcing, aquafeed producers should actively favour the sourcing of marine oils and proteins from suppliers certified by programs such as the pending Global Responsible Sourcing Standard defined by the International Fishmeal and Fish Oil Organisation". The GAA is expanding the range of species for which it can provide aquaculture standards. There is currently a working group on salmon aquaculture, which intends to produce a technical standard by 2010 (and this may include more explicit feed sustainability criteria).

Good aquaculture feed manufacturing practice

Technical guidelines for good aquaculture feed manufacturing practice (FAO, 2001) have been prepared by FAO in support of Article 9 of the CCRF concerning Aquaculture Development, and in particular in support of Article 9.4.3 of the CCRF concerning the selection and use of feeds and additives. The objective of these guidelines is to encourage adherence to good manufacturing practice (GMP) during the procurement, handling, storage, processing, and distribution of compound aquaculture feeds for farmed aquatic animals. Technical guidelines are provided under the following aspects of feed manufacturing:

- site location and design of the manufacturing facilities;
- selection and purchasing of raw ingredients, including ingredient quality control;
- receiving of ingredients;
- storage and handling of ingredients and finished goods;
- feed ingredient processing;
- feed formulation and manufacturing;
- packaging and labelling;
- warehousing and shipping;
- sampling methods and analyses;
- recalling defective or mislabelled product;
- plant cleanliness and worker safety; housekeeping;
- plant maintenance and repair;
- personnel;
- documentation.

The GMP has several guidelines with relevance to the maintenance of sustainable feed-fish stocks and sustainable use of fish in aquafeeds. The statement of purpose of the guidelines states that "assuring quality is a direct responsibility of all feed mill employees, and each will be held accountable to follow accepted procedures to implement effective good manufacturing practice (GMP) for the production of manufactured aquaculture feeds". This accountability may be extended to ensure purchasing of fishmeal and fish oil for feed manufacturing from suppliers that can assure that the products were prepared from fish sourced from sustainable feed-fish stocks. This can only be effective once many feed-fish stocks are certified for sustainability. Moreover, the statement of purpose emphasizes that the use of fish as feed and/or the use of alternative raw materials shall not compromise food safety and quality of aquaculture products and that "quality aquafeeds can only be made from the use of quality feed ingredient sources, and not from the use of inferior, spoiled, or otherwise damaged or contaminated ingredients; the protection of both human and animal health also being prime considerations in the production of quality cost-effective aquafeeds".

In order to safeguard the food safety and quality of aquaculture products from the use of fish as feed and alternative raw materials (of both animal and plant origin) in feeds, Section 6 (Selection and purchasing of raw ingredients, including ingredient quality control), Section 8 (Storage and handling of ingredients and finished goods) and Section 13 (Sampling methods and analyses) of the guidelines include the following:

- Quality feed begins with quality ingredients, and it is the manufacturer's responsibility to make sure that the ingredients used within its feeds are wholesome and safe.
- To this end, the manufacturer's buyer should have a set of standards for ingredients to be purchased and only purchase from reputable ingredient sellers that will comply with the mill's purchasing standards (Sitasit, 1995; Pike and Hardy, 1997; Boonyaratpalin and Chittiwan, 1999).
- In addition to the nutritional and analytical characteristics of the feeding stuffs, the specifications ought to include: origins and sources; any preprocessing details; hazards or limitations; and miscellaneous information including moisture content and possible non-hazardous contaminants (Tan, 1993; Kangleon, 1994; Polidori and Renaud, 1995).
- Mycotoxins found in mouldy feedstuffs may, even at very low concentrations of a few parts per billion, have detrimental effects on farmed aquatic species (Li, Raverty and Robinson, 1994; Meronuck and Xie, 2000). There are over 100 different mycotoxins, and their impact on aquaculture species is still not well understood (Trigo-Stocki, 1994; Lovell, 2000).

- The supplier's warranty should be included in the purchase order, showing suitability of an ingredient for feed use and that the ingredient is not adulterated and is in compliance with government regulations (UKASTA, 1998, 2000, 2001).
- Feed ingredients that are dry before processing should be kept dry and cool and used on a first-in, first-out basis. As a general rule, the moisture percentage should be less than 13 percent, particularly in humid and/or tropical areas (Parr, 1988; Cruz, 1996).
- While processing may dilute or kill concentrations of mould and insects, keeping equipment and storage free of dust and build-up of old feedstuffs will prevent or at least reduce the possibility of contamination of the finished feed.
- Sampling of raw ingredients and the finished products of aquaculture feed milling should be conducted routinely so as to be certain that the raw materials going into the feed and the finished feed itself meet formula specifications (Bates, Akiyama and Lee, 1995) and do not contain any defects that could be harmful to the farmer's crop or the human consumer.

The following facts and recommendations in Section 6 (Selection and purchasing of raw ingredients, including ingredient quality control) of the guidelines aim to reduce the impacts on the environment due to use of contaminated and unprocessed fish or fish processing waste in feeds:

- Low concentrations of pesticides or veterinary residues may have serious effects, not only on production of various aquaculture species, but accumulation of such residues may render aquatic species unmarketable if action levels in local regulations are exceeded (Spencer–Garrett, dos Santos and Jahncke, 1997; Boyd and Massaut, 1999; WHO, 1999; Poh Sze, 2000).
- The refeeding of feed ingredients derived from non-processed and/or processed aquaculture products (including farmed fish and shellfish processing wastes, fishmeal, shrimp meal, dead animals, etc.) should be avoided at all costs so as to prevent the possibility for the spread of disease through feed (Gill, 2000; UKASTA, 2001).

ANNEX 6

Initiatives by retailers, processors and feed manufacturers

In addition to the significant amount of work undertaken by various certification bodies, trade associations and environmental non-governmental agencies, there are also a number of policies adopted by individual retailers, processors and feed manufacturers (SFP, 2009). Several leading retailers have developed feed standards for aquaculture products they sell:

- Marks and Spencer, and Sainsbury in the United Kingdom require that feed manufacturers must take adequate steps to ensure that all of the raw materials that they use are derived from "properly managed, sustainable sources" or are "responsibly sourced" and
- Whole Foods in the United States of America demands that aquaculture feeds for salmon cannot be sourced from fisheries determined by independent, peer-reviewed science to be overfished, overexploited, depleted, or in decline.

Moreover, some of the leading aquaculture feed manufacturers (e.g. Skretting, EWOS, BioMar) have developed policies to source fishmeal and fish oil only from fisheries that are regulated and monitored as being sustainable and well managed.

These technical guidelines on the use of wild fish as feed in aquaculture have been developed in support of Article 7 (responsible fisheries management) and Article 9 (aquaculture development) of the FAO Code of Conduct for Responsible Fisheries and in particular in support of Articles 9.1.3, 9.1.4 and 9.4.3. The objectives of the guidelines are to contribute towards the development of aquaculture and the sustainable utilization of feed-fish stocks. The guidelines cover a number of issues relevant to the use of wild fish in feeds in aquaculture, including ecosystem and environmental impacts, ethical considerations on the responsible use of fish as feed, aquaculture technology and development, and statistics and information needs for managing the development of aquaculture. Specific matters relating to the management of fishery resources that may be used as feeds are briefly considered in these guidelines, as these have been dealt with in detail in separate FAO guidelines relating to fisheries management and which, *inter alia*, would also apply to feed-fish fisheries.

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