FAO Fisheries and Aquaculture Report No. 949 **FIRA/R949 (En)**

ISSN 2070-6987

Report of the

FAO WORKSHOP ON THE ON-FARM FEEDING AND FEED MANAGEMENT IN AQUACULTURE

Manila, the Philippines, 13-15 September 2010

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FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
Rome, 2010

ISBN 978-92-5-106713-0

PREPARATION OF THIS DOCUMENT

This document presents the Report of the FAO Expert Workshop on "On-farm feeding and feed management in aquaculture" that was held in Manila, the Philippines, from 13–15 September 2010. The workshop was organized by the Fisheries and Aquaculture Department Aquaculture Service (FAO FIRA) in collaboration with the Southeast Asian Fisheries Development Center Aquaculture Department (SEAFDEC/AQD), Iloilo, the Philippines. The report was prepared by Dr Mohammad R. Hasan (Aquaculture Officer, Aquaculture Service, FIRA) with assistance of Dr Thomas A. Shipton, FAO Consultant.

ACKNOWLEDGEMENTS

The FAO Fisheries and Aquaculture Department would like to gratefully acknowledge all staff of the Southeast Asian Fisheries Development Center Aquaculture Department (SEAFDEC/AQD), and in particular, Dr Joebert D. Toledo (Chief, SEAFDEC/AQD) and Dr Mae R. Catacutan (Head of Nutrition & Feed Development, SEAFDEC/AQD), for their excellent cooperation and hospitality provided during the workshop. In addition, the organizers would like to thank all the participants for their time and effort.

FAO.
Report of the FAO Expert Workshop on On-farm feeding and feed management in aquaculture. Manila, the Philippines, 13–15 September 2010.
FAO Fisheries and Aquaculture Report. No. 949. Rome, FAO. 2010. 37p.

ABSTRACT

The FAO Expert Workshop on "On-farm feeding and feed management in aquaculture" was convened in Manila, the Philippines, from 13–15 September 2010. The workshop was attended by a wide range of aquaculture researchers, development specialists and industrial experts from around the world. The workshop was convened by the FAO Fisheries and Aquaculture Department, Aquaculture Service (FIRA) and was hosted by the Southeast Asian Fisheries Development Center Aquaculture Department (SEAFDEC/AQD) based in Iloilo, the Philippines. The workshop was organized with three objectives: a) to review and analyze the existing knowledge on the application of feed management as a tool for reducing feed costs in aquaculture, b) to identify the major issues and constraints of feed management and those that need to be addressed and c) to prepare a list of recommendations to define/suggest the future course of action, including the preparation of technical manuals/guidelines for dissemination to farmers. The workshop convened both in plenary and in working groups. In the plenary, participants heard technical presentations intended to orient them to the issues and constraints pertaining to on-farm feeding and feed management. These presentations included invited reviews, case studies and synthesis of the case studies. Following several working group deliberations and a general plenary discussion, the participants identified seven primary issues that currently constrain feed use and management in aquaculture, namely: 1) limited access to information on feed and feed ingredients (availability, prices and quality); 2) poor feed preparation, processing, handling and storage at the farm level; 3) inadequate monitoring of feed and farm performances; 4) low impact of current dissemination strategies on improved feeding and feed management; 5) gaps in the understanding of the economic aspects of feed management; 6) health aspects and their implications on feed management; and 7) feed quality – lack of regulatory mechanisms. A comprehensive set of recommendations was developed to overcome the constraints that were identified, and it is anticipated that these recommendations will guide FIRA's future work in this arena. The workshop proceedings and recommendations, invited reviews, case studies and syntheses will form the basis for an FAO Fisheries and Aquaculture Technical Paper entitled "On-farm feeding and feed management in aquaculture" which will be published in due course.

CONTENTS

BACKGROUND TO THE WORKSHOP

The issue: on-farm feeding and feed management in aquaculture

It is generally accepted that feed costs account for the highest single production cost in aquaculture grow-out production systems. Typically, in intensive production systems, feed accounts for between 60 and 80 percent of operational costs. In contrast, in semi-intensive systems, feed and fertilizer use represents between 30 and 60 percent of the total cost of production.

From an economic perspective, the high costs that accrue to feed use suggest that the optimization of feed management practices will have a significant impact on the economic viability of an operation. In this regard, farmers' perceptions play a critical role. Misconceptions and a poor understanding of the effect that feed management practices have on feed utilization and productivity often result in overfeeding stock in the belief that more feed will produce more fish. In many instances, these perceptions are created and perpetuated by feed manufacturers and result in production inefficiencies and the overuse of feeds. Often high quality, commercially produced feeds are provided to aquaculture systems with little regard to the economic or nutritional rationale for their use. Such practices may result in feed wastage and the poor economic performance of the production systems. Factors affecting the poor feed utilization and resulting in high feed conversion ratios (FCRs) include the inappropriate selection of feed type (pellet type and formulation), quality and the feeding strategy. Among others, the quality of the feed is influenced by the quality and digestibility of the feed ingredients, the suitability of the formulation in terms of supplying the nutritional requirements of the culture species, the stability of the feed in the water, the storage and handling of the feed, and whether the feed is extruded or pelleted. In this regard, some farmers have shown an inclination to use extruded floating pellet, probably without attempting to use other management options to best utilize the sinking pellet or farm-made aquafeeds (please see Appendix C for definition).

Two of the most important factors that can lead to feed wastage are overfeeding and the application of poor feed management strategies by farmers. In this regard, farmers can significantly improve FCRs by regulating rations and optimizing feeding frequency, duration and timing. Importantly, the application of appropriate feed management techniques and/or improving feed quality can improve feed utilization and overall farm productivity without increasing the cost of production. There have been many studies that have indicated that while the use of high-quality feed may not necessarily provide high returns, improvements to feed management protocols can significantly increase returns, and in this regard, it has been reported that improvements to feed management practices can reduce the feed cost by 15–20 percent.

The context

Taking the above considerations into account, the FAO Fisheries and Aquaculture Department Aquaculture Service (FIRA) has initiated the work programme: "On-farm feeding and feed management in aquaculture". The objectives of this work programme are to evaluate the mechanisms available for introducing cost- and ingredient-saving feed management strategies for finfish and crustacean aquaculture and to develop suitable guidelines for their dissemination to farmers. The ultimate objective of the programme is to promote a reduction in feed use through the promotion of improved feed management practices.

The following activities have been proposed under this work programme:

a. a desktop study on the scientific information and concepts related to on-farm feeding and feed management, and a synthesis of the strategies that could be employed to reduce feed costs and the efficient use of feed ingredients;
b. reviews and country-specific case studies on feed management in selected species/species-groups that are widely cultured;
c. an expert workshop to discuss the findings of a) and b); and
d. the development of technical manuals/guidelines and regional mechanisms to disseminate them.

The species/species-groups that have been included in the work programme comprise the Nile tilapia, Indian major carps, striped catfish, whiteleg shrimp, tiger shrimp and freshwater prawn. For Asia, country coverage for the case studies includes Bangladesh, China, India, the Philippines, Thailand and Viet Nam; and for Africa, Egypt and Ghana. The broad thematic areas that were addressed in the case studies and reviews are:

- current feed types (including fertilizers) and their use in semi-intensive and intensive farming systems;
- on-farm feed production and management;
- reviews of existing feeding strategies, feed procurement, transportation and storage;
- identification of research needs; and
- identification of appropriate regulatory and legal frameworks.

In the future, country coverage may be expanded as deemed appropriate.

SCOPE AND ORGANIZATION OF THE WORKSHOP

In support of the above work programme, FIRA, in collaboration with the Southeast Asian Fisheries Development Center Aquaculture Department (SEAFDEC/AQD), organized an expert workshop entitled "On-farm feeding and feed management in aquaculture" in Manila, the Philippines, from 13-15 September 2010.

Objectives

The objectives of the workshop were to:

- review and analyze the existing knowledge on the application of feed management as a tool for reducing feed costs in aquaculture;
- identify the major issues and constraints of feed management that need to be addressed; and
- prepare a list of recommendations to define/suggest the future course of action, including preparation of technical manuals/guidelines for their dissemination to the farmers.

Outputs

The workshop proceedings, including the working group discussions and recommendations, invited reviews, country-specific case studies on feed management in selected species/species-groups, and recommendations to promote improved on-farm feed management practices, will form the basis of an FAO Fisheries and Aquaculture Technical Paper entitled "On-farm feeding and feed management in aquaculture".

Participants and workshop venue

The workshop brought together acknowledged international experts in the relevant fields, including the authors of invited reviews and case studies, and experts from government agencies, universities, international and regional organizations and private industries and organizations. The workshop was attended by 47 participants including 10 members of the local organizing committee and five observers. Participants came from Africa, Asia, Europe and North America. The workshop was hosted by the SEAFDEC/AQD and was held at the Microtel Mall of Asia, Pasay City, the Philippines.

The opening ceremony of the workshop was inaugurated by Dr Joebert D. Toledo (Chief, SEAFDEC/AQD). Introductory messages were provided by Mr Kazuyuki Tsurumi (FAO Representative, the Philippines) and Dr Mohammad R. Hasan (FAO, Rome). Dr Evelyn Grace T. De Jesus-Ayson (SEAFDEC/AQD) introduced the keynote speaker, the Honourable Proceso Alcala (Secretary, Department of Agriculture, the Philippines). Dr Mae R. Catacutan (SEAFDEC/AQD) provided the vote of thanks.

Modus operandi of the workshop

The workshop convened both in plenary and in working groups. In the plenary, participants heard technical presentations intended to orient them on the issues and constraints pertaining to on-farm feed management. These presentations included regional reviews, case studies and global syntheses.

Following the plenary sessions, the participants were divided into three working groups to discuss specific issues relating to on-farm feed management, namely:

- production and logistics (e.g. procurement, transportation and storage) of feeds (farm-made and commercial);
- feeding strategies and the assessment of feed quality and performance; and
- economics of feed management and the assessment of regulatory and legal frameworks.

Each working group elected a chairperson and a rapporteur. The groups were tasked with identifying the five major issues within their thematic areas, to prioritize these issues, recommend the actions that would be required to address them, and identify the primary stakeholders who should be responsible for the implementation of the actions required to address the issues. Following the working group deliberations and subsequent reporting to plenary, the workshop agreed on a series of recommendations and actions that could be implemented to improve on-farm feed management.

The workshop agenda and timetable is presented in Appendix I and the list of participants in Appendix II. A Technical Secretariat comprising of Dr Mohammad R. Hasan (FAO FIRA), Mr Miao Weimin (FAO RAP) and Dr Diego Valderrama (FAO FIRA) was responsible for the technical coordination of the workshop. Appendix III contains a glossary, Appendix IV presents a summary of statements made during the opening and closing ceremonies, and Appendix V provides summaries of the technical presentations.

ISSUES AND RECOMMENDED ACTIONS TO IMPROVE ON-FARM FEED AND FEED MANAGEMENT IN AQUACULTURE

The workshop identified seven major issues that need to be addressed, namely:

Issue 1: Limited access to information on feed and feed ingredients: availability, prices and quality

In many countries, there is a paucity of information pertaining to local feed ingredient supply, costs, quality (including nutrient composition) and their optimal inclusion rates for use in farm-made feed formulations. To make informed decisions about the most appropriate feed ingredients to use in their formulations, farmers/small-scale feed manufacturers (please see Appendix C for definition) need up-to-date information on ingredient availability (sources and suppliers), costs and inclusion rates in formulations. Failure to supply farmers/small-scale feed manufacturers with this information may result in available ingredients being excluded from formulations or being included at suboptimal levels.

Recommended actions:

- Identify and encourage local media and local agencies to disseminate feed ingredient information (e.g. quality, availability, cost, suppliers) at regular intervals and in local languages.
- Disseminate species-specific information on the recommended/optimal quality and inclusion rates of feed ingredients. Prior to dissemination, this information should be translated into local languages.
- Launch a pilot database (small area-specific programme) to inform farmers and feed suppliers of the current status of feed ingredient availability and price. If this intervention proves successful, it could be replicated in other areas.

Issue 2: Poor feed preparation, processing, handling and storage at the farm level

The feed preparation, processing technologies, storage and handling systems that are employed often result in feed spoilage or inefficiencies in feed formulation and usage. In the Asia-Pacific region, farm-made or semicommercial feeds, particularly for finfish farming, constitute a significant supply chain for semi-intensive, small-scale practices. Information and training on the use of the basic machinery required to make good quality farm-made/semicommercial feeds is often absent. Storage and handling systems are often rudimentary or absent, resulting in the spoilage of feed and feed ingredients and a concomitant reduction in their nutritional value. In some countries, the practice of "top-dressing" feeds with therapeutants and nutritional supplements of questionable efficacy remains problematic.

Recommended actions:

- Improve farm-made/small-scale feed manufacturing through the development and promotion of simple on-farm feed processing (grinding/pelleting/drying, etc.) technologies.
- Maintain feed quality through the development and promotion of simple feed storage systems to protect feed products from deleterious environmental parameters (sunlight, humidity, rain, etc.).
- Discourage the unregulated top-dressing of commercial and farm-made feeds.

Issue 3: Inadequate monitoring of feed and farm performances

The adoption of inappropriate feeding strategies and the inadequate monitoring of feed usage can result in feed wastage that negatively impacts production parameters. Farmers may not have the necessary knowledge required to optimize their feeding strategies, most notably the interactions between feeding behaviour and environmental parameters and the contribution that natural productivity makes to the nutritional status of the culture system. The use and efficacy of feeding devices needs to be established and promoted. The absence or poor quality of record keeping (e.g. stocking rates, feed use, growth, water quality parameters) makes it difficult to assess feed performance and the effect that feed use (quality and quantity) has on production.

Recommended actions:

- Develop feeding tables based on species, body mass, developmental stage, culture system and the associated environmental parameters.
- Promote the use of feeding devices to monitor feed consumption and feeding behaviour.
- Conduct on-farm research to evaluate and establish the nutritional contribution from natural productivity (qualitative and quantitative analyses), the nutritional status of the particular culture system, and the interaction between natural productivity and the supplemental feed requirement.
- Develop and adopt simple indicators that can be used by farmers to gauge the natural productivity in their production systems.
- Encourage farmers to improve their record keeping and monitoring activities through the use of record books and simple record tables outlining feed use, stocking, harvesting and sampling activities.
- Farmers need to be provided with training to improve their record keeping activities, and improve their abilities to assess the performance of their production systems (e.g. growth, FCR, health management, survival). Where appropriate, farmers need to be trained to undertake corrective actions to improve farm performance.

Issue 4: Low impact of current dissemination strategies on improved feeding and feed management

The existing strategies that have been developed to disseminate information to encourage farmers to adopt improved feeding and feed management practices are often ineffective. Weak extension and information dissemination networks result in low adoption rates of novel feed production technologies and management practices. Better management practices (BMPs) need to be developed and promoted at a species-specific

level, and strategies that will improve the dissemination and uptake of these practices need to be developed. A number of opportunities exist to improve dissemination strategies. These include the identification and training of key innovative farmers to demonstrate techniques and technologies to other farmers, the organization of farmer groups and cooperatives, the establishment of farmer networks to promote farmer to farmer training, and farmer field schools.

Recommended actions

- Identify good/better feed management practices and demonstrate/disseminate them to other farmers through a cluster approach (farmer networks).
- Encourage dissemination of farmers' innovations on novel feed management practices.
- Identify key leader/innovative farmers, provide leadership training and encourage them to promote BMPs. Organize farmers into groups/cooperatives or establish networks of farmers and develop farmer-to-farmer training programmes/farmer field schools.

Issue 5: Gaps in the understanding of the economic aspects of feed management

Many farmers use feeds and apply feed management practices with inadequate attention to the economic implications of their actions. Typically, feed is one of the major costs associated with aquaculture production. Subtle changes to feed management practices and changes in feed formulations can significantly impact feed costs and the overall economic performance of an operation. Farmers are often unaware of the economic weighing of their feed-related activities (choice of feed/feed management practices) and would benefit from a better understanding of the economical use of feeds on the farm.

Recommended actions:

- Farmers need to be provided with training in business management techniques that will enable them to make informed economic decisions in terms of feed choice and the feed management protocols that they apply.
- Develop and disseminate to farmers user-friendly economic tools that are designed to demonstrate the impact of feed choice and feed management on the economic viability of the farming operation.

Issue 6: Health aspects and their implications on feed management

Regular performance assessments (e.g. monitoring of fish health and survival rates, standing stock, growth) to monitor the status of the standing stock are often lacking. In this regard, farmers either fail to collect and collate the necessary information or fail to interpret performance criteria correctly. In order to maximize feed utilization, feeding protocols need to be adjusted according to stock performance criteria and indices. With respect to fish health and the effect that the health status of a cultured population has on feed consumption and utilization, there is a need to develop species-specific indicators of fish health and integrate these into feed management protocols.

Recommended action:

- At a species-specific level, develop simple and practical methodologies and indicators to assess fish health and integrate these into feed management protocols.

Issue 7: Feed quality – lack of regulatory mechanisms

Feed and feed ingredient quality remains problematic, with farmers often having little or no control over the quality of the feeds that they purchase from commercial feed manufacturers or the quality of the feed ingredients that they purchase to prepare their own feed. The use of substandard feed or feed ingredients will result in low production in the culture system and poor returns to the farmer. In this regard, many countries that have established aquaculture sectors have developed feed monitoring and product labelling systems that are designed to ensure that the farmers are aware of the quality of the feed and feed ingredients that they are purchasing.

Recommended action:

- Encourage government and farmers to monitor the quality of feeds and feed ingredients.

APPENDIX I
WORKSHOP AGENDA AND TIMETABLE

Manila, the Philippines, 13–15 September 2010

Time	ACTIVITIES
12th September	
	Arrival of the participants in Manila
13th September - Workshop day 1	
0800–0900	Registration
Session I: Opening and Welcome Remarks	
0900-0945	• Welcome remarks – *Dr Joebert D. Toledo, Chief SEAFDEC/AQD* • Message – *Mr Kazuyuki Tsurumi, FAO Representative, the Philippines* • Message – *Dr Mohammad R. Hasan, FAO, Rome* • Introduction of the keynote speaker – *Dr Evelyn Grace T. De Jesus-Ayson, SEAFDEC/AQD* • Keynote Speaker– *Honourable Proceso Alcala, Secretary, Department of Agriculture, the Philippines* • Vote of thanks – *Dr Mae R. Catacutan, SEAFDEC/AQD*
0945-1005	Coffee/Tea Break
1005-1015	Group photo
Session II: Presentation of Invited Reviews and Case studies – Nile tilapia Chair: Dr Joebert D. Toledo; Co-chair: Dr Albert G.J. Tacon; Rapporteur: Dr Thomas A. Shipton	
1015-1030	Introduction and Objectives of the Workshop – *Mohammad R. Hasan, FAO, Rome*
1030-1055	On-farm feeding and feed management in tropical aquaculture: issues, challenges and opportunities – *Amararatne Yakupitiyage, Asian Institute of Technology, Thailand*
Presentation of Case Studies and Invited Reviews – Nile tilapia	
Case Studies	
1055-1115	On-farm feed management practices for Nile tilapia (*Oreochromis niloticus*) in Ghana – *Lionel Kofi Amewusika Awity, Department of Fisheries, Ghana*
1115-1135	On-farm feed management practices for Nile tilapia (*Oreochromis niloticus*) in Egypt – *Abdel-Fattah M. El-Sayed, Alexandria University, Egypt*
1135-1150	On-farm feed management practices for Nile tilapia (*Oreochromis niloticus*) in China – *Jiashou Liu, Chinese Academy of Sciences, China*
1150-1210	On-farm feed management practices for Nile tilapia (*Oreochromis niloticus*) in Thailand – *Ram Chandra Bhujel, Asian Institute of Technology, Thailand*
1210-1230	On-farm feed management practices for Nile tilapia (*Oreochromis niloticus*) in the Philippines – *Maria Rowena R. Romana-Eguia, SEAFDEC/AQD, the Philippines*
1230-1330	Lunch
Invited Reviews	
1330-1355	An overview of tilapia feed management practices in Sub-Saharan Africa – *Abdel-Fattah M. El-Sayed, Alexandria University, Egypt*
1355-1420	On-farm feeding and feed management of tilapia aquaculture with special focus on Malaysia – *Wing-Keong Ng, Universiti Sains Malaysia, Malaysia*
1420-1520	General discussion on case studies and reviews
1520-1540	Coffee/Tea Break
Session III: Presentation of Case Studies and Invited Review – Indian major carps Chair: Dr Joebert D. Toledo; Co-chair: Dr Sena S. De Silva; Rapporteur: Dr Dave H.F. Robb	
Case Studies	
1540-1600	On-farm feed management practices for three Indian major carp species (rohu *Labeo rohita*, mrigal *Cirrhimus mrigala* and catla *Catla catla*) in Bangladesh – *Md. Rafiqul Islam Sarder, Bangladesh Agricultural University, Bangladesh*
1600-1620	On-farm feed management practices for three Indian major carp species (rohu *Labeo rohita*, mrigal *Cirrhimus mrigala* and catla *Catla catla*) in India – *R. Rama Krishna, Sri Venkateswara Veterinary University, India*
Invited Review	

1620-1645	Feed management of major carps in India with special reference to management practices adopted by carp farmers in Tamil Nadu, India – *M.C. Nandeesha, Tamil Nadu Veterinary and Animal Sciences University, India*
1645-1730	General discussion on case studies and invited review
1900-2100	Reception cocktail hosted by SEAFDEC (Abe Restaurant, Mall of Asia, Bay City, Manila)
14th September - Workshop day 2	
Session IV: Presentation of Case Study and Invited Review– catfish Chair: Dr Joebert D. Toledo; Co-chair: Dr Sadasivam J. Kaushik; Rapporteur: Dr M.C. Nandeesha	
Case Study	
0800-0820	On-farm feed management practices for striped catfish (*Pangasianodon hypophthalmus*) in Viet Nam – *Nguyen Thanh Phuong, Can Tho University, Viet Nam*
Invited Review	
0820-0840	A review of feed management practices for North African catfish in Sub-Saharan Africa – *Thomas Hecht, Rhodes University, South Africa* (*presented by Thomas A. Shipton*)
0840-0910	General discussion on case study and invited review
Session IV: Presentation of Case Studies and Invited Reviews – shrimp and prawn Chair: Dr Joebert D. Toledo; Co-chair: Dr Sadasivam J. Kaushik; Rapporteur: Dr M.C. Nandeesha	
Case Studies	
0910-0930	On-farm feed management practices for whiteleg shrimp (*Litopenaeus vannamei*) in Viet Nam – *Le Thanh Hung, Nong Lam University, Viet Nam*
0930-0950	On-farm feed management practices for giant tiger prawn (*Penaeus monodon*) in India – *A. Bala Chandra Mohan, MPEDA, India*
0950-1010	On-farm feed management practices for giant freshwater prawn (*Macrobrachium rosenbergii*) in Bangladesh – *Nesar Ahmed, Bangladesh Agricultural University, Bangladesh*
1010-1040	Coffee/Tea Break
1040-1105	Shrimp feed management: issues and perspectives – *Albert G.J. Tacon, Aquatic Farms Ltd., United States of America*
1105-1135	On-farm feed management practices in tropical aquaculture: a synthesis of case studies from selected Asian and African countries and their implications for sustained aquaculture production – *Krishen J. Rana, University of Stirling, United Kingdom*
1135-1215	General discussion on case studies and invited review and synthesis
1215-1315	Lunch
Session V: Presentation of Case Studies and Invited Reviews Chair: Dr Joebert D. Toledo; Co-chair: Dr Amararatne Yakupitiyage; Rapporteur: Mr Weimin Miao	
Perspectives of the farmers	
1315-1340	Farmer's innovation in improving feed management practices for pond culture of striped catfish – *Nguyen Ngoc Hai, Peoples Committee of Thoian Commune, Viet Nam*
Perspectives of feed industries	
1340-1405	On-farm feeding and feed management: perspectives from the feed industry – *Dave H.F. Robb, EWOS, Viet Nam*
Experience from Salmonids	
1405-1430	Control of feed intake, feeding strategies and feed management practices with special reference to salmonids – *Sadasivam J. Kaushik, INRA, France*
Environment/Economics/Regulatory	
1430-1455	Environmental consequences of feed quality and feed management – *Patrick G. White, Akvaplan-niva AS, Norway*
1455-1515	Coffee/Tea Break
1515-1540	Economic, regulatory and legal review of feed management practices in aquaculture – *Thomas A. Shipton, Enviro-fish Africa (PTY) Ltd., South Africa*
1540-1700	General discussion
1900-2100	Welcome dinner hosted by SEAFDEC (Unit 8 Café, Bay City, Ocean Boulevard, Manila)
15th September- Workshop day 3	
Session VI: Working Group Discussions Chair: Dr Mohammad R. Hasan; Co-chair: Dr Krishen J. Rana; Rapporteur: Dr Ram Chandra Bhujel/Marc Metian	
0800-0820	Mechanisms and guidelines for Working Group (WG) Discussions – *Diego Valderrama, FAO, Rome*

0820-1000	Working Group break up for discussion on key thematic areas
1000-1200	Working Group preparation for plenary presentation
1030-1045	Coffee/Tea Break
1200-1220	Working Group I **–** presentation to plenary – *A. Bala Chandra Mohan*
1220-1240	Working Group II **–** presentation to plenary – *Dr Amararatne Yakupitiyage*
1240-1300	Working Group III **–** presentation to plenary – *Dr Thomas A. Shipton*
1300-1400	Lunch
1400-1530	Plenary discussion of working group recommendations
1530-1545	Coffee/Tea Break
Session VII: Presentation of Final Workshop Recommendations in Plenary	
1545-1700	Presentation of summary recommendations of the workshop Discussion, next step **–** *Mohammad R. Hasan*
1700-1730	Wrap up and closure – *Mohammad R. Hasan and Mae R. Catacutan*
1900-2100	Closing dinner hosted by FAO (Fish & Company, Ocean Boulevard, Bay City, Manila)
16th September 2010	
	Participants depart Manila

APPENDIX II
LIST OF PARTICIPANTS

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APPENDIX III
GLOSSARY

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, the planning, development and operation of aquaculture systems, sites, facilities and practices, and the production and transport (modified from FAO, 1997[1]).

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 Aquatic Animal Health Code, available at http://www.oie.int/eng/normes/fcode/en_glossaire.htm#sous-chapitre-2).

Better management practices (BMPs)[2]
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').

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.

Complete feed
A nutritionally adequate feed for animals other than man that is compounded by specific formula 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 (modified from FAO, 2001[3]).

Compound feed
A feed composed of several ingredients 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).

Crumble (aquafeed)
Aquafeed produced in granular form (modified from FAO, 2001).

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

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

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[1] FAO. 1997. *Aquaculture development.* FAO Technical Guidelines for Responsible Fisheries No. 5. Rome, FAO, 40 pp. (available at ftp://ftp.fao.org/docrep/fao/003/W4493e/W4493e00.pdf).
[2] Adapted from the FAO/NACA/UNEP/WB/WWF International Principles for Responsible Shrimp Farming. Network of Aquaculture Centres in Asia-Pacific (NACA). Bangkok, Thailand. 2006.
[3] FAO, 2001. *Aquaculture development. 1. Good aquaculture feed manufacturing practice*. FAO Technical Guidelines for Responsible Fisheries No. 5, Suppl. 1. Rome, FAO. 47 pp. (available at ftp://ftp.fao.org/docrep/fao/005/y1453e/y1453e00.pdf)

Farm-made aquafeed[4]
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.

Feed(s)
Edible material(s) which are consumed by animals and contribute energy and/or nutrients to their diet. Usually refers to animals rather than man (modified from FAO, 2001).

Feed additives
Chemicals other than nutrients for fish that are approved for addition to their feed (FAO/WHO, 2009[5]). 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 requires 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 one kilogram of fish live weight) (FAO Glossary of Aquaculture, 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 one kg of fish, while the economic FCR takes into account all the feed used, meaning that the effects of feed losses and mortalities, for example, are included (Aquamedia, available at www.piscestt.com/home/FAQ/Answers/ans8_en.asp).

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

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, semiprocessed or raw that is intended to be fed directly to aquatic animals (OIE Aquatic Animal Health Code, available at http://www.oie.int/eng/normes/fcode/en_glossaire.htm#sous-chapitre-2).

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 http://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 http://www.fao.org/fi/glossary/aquaculture/default.asp).

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

Ingredient, feed ingredient

[4] Hasan, M.R., Hecht, T., De Silva, S.S. & Tacon, A.G.J. (eds.). 2007. *Study and analysis of feeds and fertilizers for sustainable aquaculture development*. FAO Fisheries Technical Paper No. 498. Rome, FAO, 510 pp.
[5] WHO/FAO. 2009. *Code of practice for fish and fishery products.* 1st Edn., Rome, FAO, 144 pp. (available at ftp://ftp.fao.org/codex/Publications/Booklets/Practice_code_fish/Practice_code_fish_2009_EN.pdf).

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 Aquatic Animal Health Code, available at http://www.oie.int/eng/normes/fcode/en_glossaire.htm#sous-chapitre-2).

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

On-farm feeding (of fish/aquatic animals)
Feeding activity that takes place on the farm and is done by the farmers. It includes actual feeding and feeding-related activities but not feed production *per se.*

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

Semicommercial 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.

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 run, have low to moderate input levels and use limited external labour. (FAO Glossary of aquaculture, available at http://www.fao.org/fi/glossary/aquaculture/default.asp).

Small-scale farmers[6]
Resource-poor individuals or groups of people involved in small-scale aquaculture production, i.e. aquaculture production facilities and processes with small production volume and/or relatively small surface area and typically lacking technical and financial capacity and other resources to support individual certification.

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 "semicommercial aquafeeds" or "farm-made feeds".

Stakeholder[7]
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.

Trash fish/low-value fish[8]

[6] Adapted from the Report of the First Expert Workshop on Aquaculture Certification held in Bangkok, Thailand. March 2007.
[7] FAO, 2003. *The ecosystem approach to fisheries.* FAO Technical Guidelines for Responsible Fisheries No. 4, Suppl. 2. Rome, FAO. (available at http://www.fao.org/DOCREP/005/Y4470E/y4470e00.htm).

Fish that have a low commercial value by virtue of their low quality, small size or low consumer preference – such fish are either used for human consumption (often processed or preserved) or used for livestock/fish production, either directly or through reduction to fishmeal and/or fish oil.

[8] Funge-Smith, S., Lindebo, E. & Staples, D. 2005. *Asian fisheries today: The production and use of low value/trash fish from marine fisheries in the Asia-Pacific region.* FAORAP, Bangkok, RAP Publication 2005/16.

APPENDIX IV
OPENING AND CLOSING REMARKS

Welcome

Dr Joebert D. Toledo

Dr Toledo, Chief, Southeast Asian Development Center Aquaculture Department (SEAFDEC/AQD), greeted the workshop delegates and outlined the role that the SEAFDEC/AQD plays in promoting tropical aquaculture. Dr Toledo outlined AQD's historical work in developing aquaculture feeds and the organization's focus on assisting sectoral development through the promotion of science-based, sustainable aquaculture technologies and practices. In this regard, he acknowledged the critical role that nutrition plays in terms of sectoral development, most notably through the development of appropriate feed formulations, manufacturing technologies and the promotion of sustainable feed management strategies.

Opening remarks and brief about the workshop

Message – *Mr. Kazuyuki Tsurumi*

Mr Kazuyuki Tsurumi, the FAO Representative in the Philippines, expressed his appreciation at being invited to the workshop. Mr Tsurumi noted that in the future, the availability of feeds will be one of the most important issues in terms of sustaining and promoting sectoral growth, and therefore suggested that the current workshop focusing on feeding and feed management is most timely. He suggested that the selection of the Philippines as the workshop venue is most appropriate, as the country has a long history of aquaculture production and at a global level is now represented as one of the top-ten producer countries. In this regard, he suggested that the Philippines would be a suitable country to undertake feeding and feed management studies to evaluate mechanisms available for introducing cost and ingredient-saving feed management strategies for finfish and crustacean aquaculture. He finished by reiterating the FAO's commitment to helping countries to manage their fisheries and aquaculture sectors effectively and to ensure that fish continues to be a significant source of food, livelihood and trade for future generations.

Message – *Dr Mohammad R. Hasan*

Dr Mohammad R. Hasan, Aquaculture Officer (FIRA) of FAO in Rome, expressed his gratitude to be able to host this important FAO expert workshop. He commenced by thanking Dr Toledo for his introduction and the SEAFDEC/AQD for hosting the workshop in the Philippines. He welcomed and expressed his thanks for the attendance of the delegates. Dr Hasan indicated that the workshop had been convened in order to discuss on-farm feeding and feed management practices with the intention that the outcomes of the workshop would provide direction, future guidance and recommendations for the FAO's activities in this important field. He indicated that the invited reviews and case study reports would be compiled and published as an FAO technical paper.

Keynote Speaker - *Honourable Proceso Alcala,* Secretary, Department of Agriculture, the Philippines

Read by Dr Rosa F. Macas, Director, Bureau of Fisheries and Aquatic Resources (BFAR) Region 4-A.

The honourable Proceso Alcala welcomed the delegates, thanked them for their attendance and indicated that the Philippines was pleased to host the workshop. He went on to describe the scale of the aquaculture and fisheries sector in the country and its growth trends and indicated that in 2009, the sector was worth in the region of USD3.6 billion, accounting for approximately 25 percent of the country's agricultural production. Of this production, approximately half (47 percent) was attributed to aquaculture. He suggested that to ensure the continued development of the sector, it is crucial that sustainable technologies are developed and that the resources required for enhancing aquaculture productivity and profitability are secured. In this regard, he noted that there was a need for continued advocacy for improved feed management strategies, including the use of optimal combinations of fertilizers, feed ingredients and

manufactured feeds. In response to these needs, the Philippine Department of Agriculture – through the Bureau of Fisheries and Aquatic Resources – has placed greater emphasis on RD&E activities on fish nutrition and the development of mechanisms to achieve improved food conversion efficiency and reduced production costs. In addition, the government has also established small-scale feed formulation projects and feed-milling centers in strategic areas around the country. The Honourable Proceso Alcala finished by expressing his hope that the workshop will result in improvements to feed management strategies and by doing so, improve the efficiency of the fish farming industries in our respective countries.

Wrap up and closure

The workshop was wrapped up by Dr Mohammad R. Hasan (FAO FIRA), who indicated that he was satisfied that the objectives of the workshop had been achieved and thanked all the participants, the organizers and the Secretariat for helping to make the event the success that it was. He wished everyone a safe trip home.

APPENDIX V
SUMMARIES OF TECHNICAL PRESENTATIONS

Case Studies

On-farm management practices for the Nile tilapia (*Oreochromis niloticus*) in Ghana

Lionel K. Awity, Ministry of Fisheries, Accra, Ghana

On-farm feed management practices have been assessed at some randomly selected locations in the country. The assessment concentrated on the Nile tilapia (*Oreochromis niloticus*) and investigated various aspects of feed use in earthen fishpond and fishcage farms. Earthen fishpond farms are widely scattered throughout the country, while fishcage farms are concentrated on the Volta Lake. In 2008, fish production from aquaculture was 5 596 tonnes. This figure represents approximately one percent of domestic fish production. Fish farming is an emerging industry in Ghana, with Nile tilapia accounting for over 80 percent of aquaculture production.

For this study, owners or managers of the fish farms were interviewed using a predefined, structured set of questions. The investigation focused on issues such as current feed use and management practices, various aspects of industrially produced commercial/complete feeds, farm-made and supplementary feeds, quality and costs. Information was solicited on feed procurement, transportation and storage. The investigation also looked at existing feed management strategies and practices, including feed types, feed additives, feed volumes, feeding frequency and feed dispensation, growth, FCRs and feed monitoring. The assessment of feed management and utilization was undertaken to identify the knowledge gaps and establish the areas of improvement for on-farm feed management, research needs and the legislative framework for feed use and management.

Three types of feeds are in use: farm-made, locally produced and imported commercial feeds. On the earthen fishpond farms, it is evident that fish feed production and use are not managed optimally, and thus maximum returns to the fish farmer are not always attained. Fishcage farmers primarily depend on the use of imported commercial feeds. With respect to feed quality, farm-made feeds for Nile tilapia were coarse to touch, crumbly, powdery and sinking. In contrast, imported feeds were in pellet form, smooth to touch and mostly floating. Research needs and the need for regulations to ensure the certification of fish feeds, both imported and locally produced were identified. The need for improved storage of feeds was highlighted. With respect to earthen fishpond farmers, major knowledge gaps exist in feed formulation, preparation, use and management.

On-farm management practices for the Nile tilapia (*Oreochromis niloticus*) in Egypt

Abdel-Fattah M. El-Sayed, Alexandria University, Alexandria, Egypt

This survey was carried out during the period February to May 2010 to evaluate on-farm feed management practices for Nile tilapia (*Oreochromis niloticus*) in Egypt. Data were obtained from 64 tilapia farmers and six aquafeed mills from the three major tilapia production governorates (Kafr El-Shaikh, Behaira and Sharkia), which collectively produce over 80 percent of the country's farmed tilapia.

The production of farmed Nile tilapia increased from only 24 916 tonnes in 1990 (representing 2.3 percent of total aquaculture production) to 386 186 tonnes in 2008 (representing 55.7 percent of total aquaculture production). In Egypt, tilapia culture is primarily practiced in semi-intensive brackishwater pond systems. In 2008, over 80 percent of the tilapia produced (315 253 tonnes) was in semi-intensive systems. Nevertheless, polyculture systems using tilapia, mullets and carps remain common in many areas; however, these polyculture systems are gradually being replaced with monoculture systems using all-male Nile tilapia. Approximately 75 percent of surveyed tilapia farmers have adopted monosex tilapia culture as their preferred culture option. Intensive Nile tilapia culture in earthen ponds, tanks and cages is slowly spreading in many areas of the country.

The available information indicates that there are no standardized feeding and fertilization strategies, and most tilapia farmers are unfamiliar with optimal fertilization regimes. Poultry manure is the most important organic fertilizer used in tilapia ponds. It is estimated that the amount of poultry manure used in aquaculture represents about 3 to 7 percent of the country's total poultry manure production. However, in some areas of the study region, tilapia farmers no longer use organic fertilizers. Instead, they only fertilize their ponds with chemical fertilizers. Both urea and superphosphate are generally used for pond fertilization. Generally, application rates are in the region of 20 to 40 kg superphosphate/ha (about 30 kg/ha on average) and 10 to 25 kg of urea/ha (about 20 kg/ha on average).

The commercial aquafeed industry in Egypt is growing at a rapid rate. The number of aquafeed mills increased from only five in 1999 to 31 mills in 2009. Current aquafeed production is about 420 000 tonnes/year, of which about 280 000 tonnes (65 percent) is used for tilapia culture. Compressed (sinking) pellets, with a crude protein (CP) content of 25 percent, comprise the bulk of the aquafeeds produced. Extruded aquafeed technology was introduced in the mid-1990s, and the market for these feeds is growing. Tilapia farmers show a preference for extruded feeds as compared to compressed feeds, as they show improved feed conversion ratios (FCR) and are highly digestible. Indeed, FCRs using compressed feed for Nile tilapia range from 1.5 to 2.5, while those for extruded feeds range from 1.1 to 2.

Hand feeding, twice per day (early morning and afternoon), is the most common feeding practice among tilapia farmers. However, the use of locally made demand feeders is expanding, especially among medium- and relatively large-scale farmers.

It was estimated that formulated feeds were used for approximately 48 percent of total tilapia production. Feeding for the remaining production was attributed to natural food produced through pond fertilization. Farm-made feeds are rarely used by Egyptian tilapia farmers; none of the surveyed farmers reported using such feeds. However, some farmers in remote areas who produce fish primarily for family subsistence make their own farm-made feeds.

Between 50 to 75 percent of the feed ingredients that are used in aquafeeds in Egypt are imported. Over the past decade, the prices of these ingredients have increased substantially. As a result, the prices of both compressed and extruded tilapia feeds have increased 2 to 2.5 fold during this period.

The main constraints faced by tilapia farmers and the aquafeed industry include the escalating price of formulated feeds and feed ingredients, high customs tariffs on feed ingredients, poor handling and storage of feed and feed ingredients, limited access to finance for small-scale farmers and the unavailability of larval and fingerling feeds. Recommendations to address these issues are provided.

On-farm management practices for the Nile tilapia (*Oreochromis niloticus*) in southern China

Jiashou Liu, Zhongjie Li, Xiaowu Li & Yaohua Wang, Chinese Academy of Sciences, Wuhan, China

China is the largest producer of Nile tilapia (*Oreochromis niloticus*) in the world. The main production provinces are located on the southeastern coast, principally Guangdong, Guangxi, Hainan and Fujian. In 2006, production from these four provinces was 998 000 tonnes, accounting to about 90 percent of the country's tilapia production. The tilapia subsector represents the 6th largest subsector after silver carp (*Hypophthalmichthys molitrix*), bighead carp (*H. nobilis*), grass carp (*Ctenopharyngodon idellus*), common carp (*Cyprinus carpio*) and Crucian carp (*Carassius carassius*). This paper reviews on-farm feeds and feed management practices in Guangdong and Hainan provinces. The review describes on-farm feeding and feed management practices in different tilapia farming systems and assesses the economic impact of these practices. Particular attention is given to the status and problems for the on-farm use of feeds. Practical measures that can be taken to promote more efficient use of feed resources are provided.

On-farm management practices for the Nile tilapia (*Oreochromis niloticus*) in Thailand
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This document was prepared as part of a study on on–farm feed management practices for Nile tilapia (*Oreochromis niloticus*). The majority of the information provided in this document was collected from key informants, especially tilapia hatchery operators and grow-out farmers throughout Thailand. Informants were interviewed using a semistructured questionnaire. A considerable amount of information was derived from published literature and from a conference organized by the Thailand Aquaculture Society (TAS) on 31 January 2010. The survey covered pond-culture farms ranging from 0.5 ha to over 20 ha in size and river-based cage farms ranging in size from 4 cages up to 200 cages. The hatcheries ranged in size from those producing less than 1 million fry per annum to large commercial-scale hatcheries producing up to 240 million fry per annum. Tilapia pond culture is very common in Thailand, especially in rural areas. While almost all of the subsistence tilapia farms use polyculture systems, most of the commercial farms operate single species mono-sex culture systems. Silver barb (*Barbonymus gonionotus),* snakehead (*Channa* spp.), hybrid catfish (*Clarias gariepinus* x *C. macrocephalus*), common carp (*Cyprinus carpio*) and some Chinese and Indian major carps are among the species used for polyculture. Almost all the farmers fertilize their ponds to enhance planktonic growth and productivity. The fertilizers in use include chicken manure and/or chemical fertilizers. Feeding is supplementary. Although, high-quality feeds are available in Thailand, the high price of these feeds combined with a low sale price of fish results in their limited use. In this regard, to reduce production costs and thereby maximize profits, farmers often elect to use cheaper (average price 12THB/kg) feeds and locally available feed by-products. Almost all the farmers hand feed twice daily and achieve relatively good growth rates (1 g/fish/d). Feed conversion ratios (FCRs) are normally lower than 1.0. However, as the fish receive a considerable amount of nutrients from natural foods (phyto- and zooplankton), FCR values relating to the use of supplementary feeds need to treated with caution. In addition, the feeds/ingredients that are used are not of a standard quality in terms of nutrient content and moisture, further exacerbating the difficulties in assessing their performance. Cage farming in rivers and canals is becoming increasingly popular. Almost all the cage farmers practice single species culture, either red variety or black Nile tilapia. Although commercial pellets are used, the feeds are normally of low quality, i.e. low in crude protein, (around 20 percent of the diet). On average, cage farmers feed three times a day and achieve FCRs between 1.4–1.8 and growth rates of 2–3 g/d.

Feeds and feed ingredients are transported by pickup truck by farmers or delivered to the farms by the manufacturers/dealers. Typically, farmers store the feeds-in-sacs in cool rooms, either at home or on their farms. However, before feeding they normally keep feeds in large plastic buckets on pond dikes, on the cages or at nearby riverbanks. This practice may result in the quality of feed deteriorating due to high humidity and the extreme heat of the sun during the daytime. In general, raising tilapia using high-quality commercial feeds is not profitable, and the selection of suitable feeds is viewed as one of the most important determinants of profitability. In this regard, training is required to improve the formulation and preparation of good quality feeds, improve feeding practices (such as ingredient selection), ensure proper storage and the feeding of high-quality finisher diets at the end of the production cycle. In this regard, the production and distribution of a manual in the local language outlining best farming practices should be considered.

On-farm management practices for the Nile tilapia (*Oreochromis niloticus*) in the Philippines
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In recent years, commercial tilapia culture in the Philippines has grown. Farmers have become increasingly aware of the importance of introducing new husbandry methods such as the intensification of culture technologies, the use of novel feed ingredients and quality industrial aquafeeds, applying cost-effective feeding strategies, efficient pond fertilization methods and introducing improved genetic strains. This report presents a case study that was designed to: a) assess current tilapia feed management practices in the

Philippines; b) establish recent advances and innovations in tilapia nutrition in the country, including the use of alternative feed ingredients, nutritionally complete commercial tilapia feeds and improved feeding management methods; and c) evaluate the impact that these innovations have had on improving local tilapia production. Thirty-two farmers from selected tilapia cage hatcheries, pond hatcheries, grow-out cages and ponds in Regions III and IV-A were interviewed to establish current trends in farm feed management practices. Particular focus was placed on feed preferences, quality, procurement and storage methods, and feeding strategies. Supplementary information was sought from the published scientific literature, popular articles and relevant websites. Results from the case study highlight the importance of farmers being trained and kept abreast of improvements in all aspects of aquaculture nutrition. Recommendations to increase tilapia production through the improvement of feed management practices and the nutritional status of the farms are described, and the importance for local regulatory agencies to strictly implement aquafeed quality and nutrient standards is emphasized.

On-farm feed management practices for three Indian major carp species: rohu (*Labeo rohita*), mrigal (*Cirrhinus cirrhosus*) and catla (*Catla catla*) in Bangladesh

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Traditionally, Indian major carps have been considered the prime aquaculture candidates in Bangladesh. There are three production systems for the major carps *viz*. broodstock and fry production systems, nursery systems and grow-out systems. The production of major carps in all three systems depends on several factors. Among these, the provision of quality seed and the quality of supplemental feed and its administration are the most important. In terms of improving yields from extensive and semi-intensive aquaculture systems, the addition of nutrients through supplemental feeding is a prerequisite for sustainable fish production. In order to establish the current status of supplemental feeding in the sector, a field survey focusing on different production systems was conducted in four major producer regions – Jessore, Mymensingh, Comilla and Rajshahi. Three separate questionnaires based on the different production systems were developed, pretested and deployed. A total of 85 farmers were interviewed, and information collected included the selection of fish species, species composition and density, pond preparation and its management, natural food production, supplemental feed, its preparation and presentation, the preservation of quality and production statistics.

In the broodstock system, variability was found in the selection of fish species, stock composition, broodstock management and supplemental feed and feed management practices. All the hatchery operators provided supplemental feeds to broodstock, either in the form of a pellet or wet dough; however, it was evident that some farmers were not supplying nutritionally balanced formulations. With respect to the nursery systems, similar production strategies in terms of species selection, stocking rates, rearing and supplemental feeding were found across the farms. Mustard oil cake is commonly used to feed the fry, and while this does not provide the necessary nutrients for optimal growth, its use was attributed to the farmers' lack of knowledge of the nutritional requirements of the species. In the grow-out system, variation was found in the selection of species, composition of stock, stocking density and water management practices, and the use of supplemental feeds varied between the regions. The majority of farmers undertook regular supplemental feeding. In some cases, a lack of funds to purchase feeds resulted in the adoption of irregular feeding schedules. Farm-made supplemental feeds, locally produced pelleted feeds and industrially manufactured pelleted feeds were used by the farmers. The poor quality of the farm-made feeds suggested that some nutrients were probably lost during ingestion. It was evident that farmers were inadequately trained on issues pertaining to the nutritional requirements of the culture species, feed production, presentation and nutrient loss, the storage of feed, and the recording of production data and the calculation of feed conversion ratios.

On-farm feed management practices for three Indian major carp species: rohu (*Labeo rohita*), mrigal (*Cirrhinus cirrhosus*) and catla (*Catla catla*) in Andhra Pradesh, India

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This case study report was based on the results of a random survey comprised of 106 interviews conducted from December 2009 to July 2010 in three different regions of Indian major carp culture in Andhra Pradesh, India. The primary species groups surveyed were rohu (*Labeo rohita*), catla (*Catla catla*) and mrigal (*Cirrhinus cirrhosus),* but other species cultured together with Indian major carps were also recorded. The primary area covered in the survey was the Kolleru region and the surrounding areas in the Krishna and West Godavari districts of the state. The two other survey areas were Nellore District, where Indian major carp culture is practiced at a lower intensity compared with Kolleru carp culture, and East Godavari District where Indian major carps are mostly cultured in polyculture systems, either with tiger shrimp (*Penaeus monodon)* or freshwater prawns (*Macrobrachium rosenbergii*). The main data recorded from the survey described the production and availability of mash feed ingredients and commercial pelleted feeds, the sale of feeds and feed ingredients, the use of feed additives, feeding rates, feed conversion ratios, feeding frequencies, feed dispensation methods, feed ingredient quality issues, farmers' feed preferences, strategies adopted by farmers to save feed costs, and the use of manures and fertilizers. Farmer perceptions were recorded, and the regulations and controls relating to Indian major carp culture and the use of antibiotics and other pharmacologically active substances were also recorded.

The study revealed that in all the Indian major carp culture systems, mash feed is the most popular and widely used feed type, with de-oiled rice bran representing the principal feed ingredient, followed by groundnut cake and cotton seed cake. All the carp farmers in the survey used de-oiled rice bran, followed by groundnut cake (56.4 percent of farmers), cotton seed cake (39.7 percent of farmers) and raw rice bran (29.5 percent of farmers), and other mash feed ingredients. The inferior quality of mash feed ingredients, especially the de-oiled rice bran but also the groundnut cake and cotton seed cake, is a significant problem for the farmers. A third of the farmers reported using commercial pellets for supplementing mash feeds, with most electing to use sinking pellets. Since 2007, there has been a sudden increase in the use of the commercially produced feeds. The increase in feed use has primarily been attributed to the increased production of striped catfish (*Pangasianodon hypophthalmus*), commonly called "pangas" in the state.

The most common feeding method across the regions surveyed was the bag feeding method, for which there are two variants – rope feeding and pole feeding. In Nellore, some farmers practice hapa feeding, and in East Godavari District, farmers use the bag feeding method and in addition, feed fish in mixed culture ponds in hapa enclosures.

In the nursery and grow-out ponds, the commonly used feed ingredients include groundnut cake, de-oiled rice bran and raw rice bran. Feed distribution is via simple broadcast feeding. Rohu and sometimes catla broodstock are collected from selected culture ponds during the breeding season. Feeding practices for the rohu broodstock are generally similar to those practiced in the grow-out ponds. However, catla broodstock is fed a dedicated soybean cake, dry fish and mineral mixture diet.

Issues and research requirements to improve nutrition, supplementary feeds, natural food and feed management practices in semi-intensive Indian major carp culture systems are outlined.

On-farm feed management practices for striped catfish (*Pangasianodon hypophthalmus*) in Mekong River Delta, Viet Nam

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The Mekong Delta is considered as the most important region for aquaculture production in Viet Nam and in 2008 accounted for approximately 75 percent of the total national aquaculture production (IFEP, 2009). The delta has a total freshwater area of 641 350 ha, is characterized by a diverse number of aquaculture activities and has significant potential for increasing aquaculture production. While there are a number of species that are commercially produced in the delta, the striped (or tra) catfish is the most important. In

2008, the production of this fish reached 1 200 000 tonnes (Nguyen and Dang, 2009)[9].

The rapid expansion of tra catfish farming is the result of a number of factors. In this regard, improvements to feed and feed management practices have played a key role in the development of the sector. The feed and feeding of tra catfish have changed over time. In the early days of the tra catfish farming industry, farm-made feeds (FMFs) were used across all culture systems including cages, pens and ponds. In 1995 and 1996, manufactured pelleted feeds (MPFs) were introduced to cage culture operations, and since 2004, the use of MPFs has gradually been accepted by tra catfish farmers. The survey indicated that 63.3 percent, 17.4 percent and 19.3 percent of farms use either MPFs or FMFs or a combination of MPFs and FMFs, respectively. It is evident that during the past five years, the tra catfish MPF industry has been developing rapidly in Viet Nam; the yearly production increased from 300 000 tonnes in 2004 (Tran, 2005)[10] to 2 200 000 tonnes in 2008.

The feeding practices for tra catfish are dependent on the stock size and feed types. The feeding rates for MPFs vary from 2 to 5 percent of body weight per day according to fish body weight, while the feeding rates for FMFs are about 1–2 percent higher. Fish less than 100 g are fed three times daily, while one feeding is applied to stock of 800 g and above. The feed conversion ratios vary with feed type and range from 1.63 for MPFs to 2.9 for FMFs. Feed costs represent the largest portion of the total production cost. The feed cost of tra catfish fed either MPF, FMF or a combination of MPF and FMF represents 82.9, 77.4 and 79.0 percent of the total production costs, respectively. The profit of tra catfish farming depends greatly on the feed cost and farmgate price.

There are several feed management issues that require further research. These include establishing the nutritional requirement of larger stock sizes, determining on-farm feed digestibility coefficients, optimizing feeding strategies and improving the use of FMFs.

Case study on the feed use and feed management in whiteleg shrimp (*Litopenaeus vannamei)* farming in Viet Nam

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In 2009, a survey of 97 whiteleg shrimp (*Litopenaeus vannamei*) farmers in central and south Viet Nam was undertaken. It was established that farmers stocked at very high densities – between 100 to 200 shrimp per ha, and harvested after 80 to 100 day production cycles. Smaller shrimp (12–15 g) are harvested in less than 80 days. Farmers rely on manufactured feeds and rarely use supplemental feeds. The manufactured feeds contain high protein levels ranging 36 to 44 percent that vary according to the size and nutritional requirements of the shrimp. The feed conversion ratio varied between 1.1:1 and 1.2:1, and the shrimp yields ranged between 10 and 20 tonnes/ha/crop depending on the stocking density. It was established that farmers in central Viet Nam use smaller ponds and often stock at higher densities than farmers in the Mekong Delta (south Viet Nam). As a result, the shrimp yields per ha in central Viet Nam are often higher, the culture period longer and the harvested size smaller than those in South Viet Nam.

The production costs accruing to whiteleg shrimp farming were analyzed. Feed costs represent 66-68 percent of production costs. The cost of seed and fuel/electricity accounted for between 8 and 10 percent of production costs, while labour accounted for 2 percent of production costs. The total production costs/ha/crop were USD32 000 and USD16 500 in central and south Viet Nam, respectively.

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[9] Nguyen, T.P. & Dang, T.H.O. 2009. Striped catfish (*Pangasianodon hypophthalmus*) aquaculture in Viet Nam: an unprecedented development within a decade. *In* S.S., De Silva & F.B. Davy, eds. Success *Stories in Asian aquaculture*, pp. 133–149. Springer, NACA and IDRC, Dordrecht, Bangkok and Ottawa.

[10] Tran, V.N. 2005. *Evaluation of the use of locally available feedstuffs for catfish (Pangasianodon hypophthalmus) cage culture in An Giang Province.* MA Thesis, College of Aquaculture and Fisheries, Can Tho University, 79 pp. (in Vietnamese)

The benefit-cost ratios were 1.69 and 1.75 in central and south Viet Nam, respectively. The analysis suggests that whiteleg farming in central Viet Nam is more intensive but less profitable than farming in South Viet Nam.

While there remains potential to develop the shrimp culture sector in South Viet Nam, production in central Viet Nam has probably reached its peak. Disease outbreaks are a cause for concern, most notably in central Viet Nam.

On-farm feed management practices for giant tiger prawn (*Penaeus monodon*) in India

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This paper is based on a case study of on-farm feed management practices on giant tiger prawn (*Penaeus monodon*) farms in India. Ninety percent of prawn farming activities in India are based on small-scale farmer models. The results of the study suggest that feed represents the major cost input in prawn farming, accounting for between 50 and 60 percent of production costs. Therefore, reducing feed costs through the adoption of efficient feed management practices is an essential prerequisite to cost-effective production. The paper provides an assessment of current feed management practices and provides practical measures that can be taken to promote the efficient use of feed resources. In the study, 36 percent of the ponds recorded FCRs between 1.2 and 1.4, with 27 percent of the ponds recording FCRs between 1.4 and 1.6. Only 3 percent of the ponds recorded FCRs over 2. Farmers indicated that a FCR of less than 1.5 was considered good. The good FCR observed across the various farming systems in the study demonstrates the positive impact of improved feed management practices as implemented by the study farmers.

On-farm feed management practice for freshwater prawn farming in southwest Bangladesh

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This paper examines the feed management practices of freshwater prawn (*Macrobrachium rosenbergii*) farming under three different farming systems in southwest Bangladesh. Based on the production technology, prawn farming is classified as extensive, improved-extensive and semi-intensive. Most farmers practice prawn farming in rice fields, with their primary dependence being on prawn, fish, rice and dike crops. Prawn farms employing extensive feeding practices depend solely on snail meat, while the improved-extensive category refers to the use of farm-made aquafeeds comprising mixtures of locally available feed ingredients (e.g. rice bran, mustard oilcake, fishmeal, oyster shell, salt and vitamins). Prawn farms based on semi-intensive feeding practice use industrially manufactured pelleted feeds. The average annual prawn production per hectare in semi-intensive farming (718 kg) was higher than in improved-extensive (489 kg) and extensive (351 kg) farming. The higher yields were mainly attributed to the higher levels of inputs, including seed, feed, fertilizer and labour. The average annual production costs were estimated at USD2 875/ha in semi-intensive farming systems, USD2 088/ha in improved-extensive systems, and USD1 457/ha in extensive farming systems. Feed cost comprises the second highest operational cost in extensive (15 percent) and improved-extensive (25 percent) farming systems, and the highest operational cost in semi-intensive farming systems (33 percent). Despite the higher production costs per hectare, the average annual net return was higher in semi-intensive farming systems (USD2 162) compared with improved-extensive (USD1 445) and extensive (USD1 092) farming systems.

Although snail meat feeding in extensive farming systems is suitable for resource-poor farmers because of lower production costs, this feeding system usually attains a relatively low level of production per hectare, and therefore the net return in this system is low. Moreover, due to an inadequate supply of snails, this feeding system may not be sustainable. Higher net returns per hectare are obtained in the semi-intensive farming systems, as producers appear to be able to afford more inputs, including industrially manufactured pelleted feeds. However, the high level of investment required for semi-intensive farming and problems associated with access to capital would make it difficult for large numbers of small-scale farmers to engage in this type of farming. The quality of industrially manufactured pelleted feed is also of concern, notably

due to the presence of banned antibiotics. It is therefore concluded that farm-made aquafeed is the best alternative for resource-poor farmers in terms of availability, quality and price. This article concludes that farm productivity as well as profitability can be increased through a combination of increased feeding rates of farm-made aquafeeds and better management practices.

Synthesis of Case Studies

On-farm feed management practices in tropical aquaculture: a synthesis of case studies from selected Asian and African countries and their implications for sustained aquaculture production

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The sustainability of attained aquaculture production and the required expansion to meet projected demands to ensure the delivery for national food sovereignty and to secure livelihoods, especially in rural areas, is increasingly under scrutiny in several fora. The availability and cost of aquafeeds is at the center of such scrutiny since feed inputs, irrespective of source, type or geographic location account for 50–80 percent of production costs.

This presentation contributes to this forum through the synthesis of 11 case studies in eight countries on on-farm feed management practices based on farmer experiences in Africa (Ghana and Egypt) and Asia (China, Thailand, the Philippines, India, Bangladesh and Viet Nam). Through these case studies, the feed management practices for key farmed finfish species (Nile tilapia, Indian major carps and striped catfish) and shellfish (whiteleg shrimp, giant freshwater prawn and black tiger prawn) are assessed, with the objective of understanding current practices, ideally leading to improved practices to reduce production costs and improve production efficiencies in warmwater aquaculture systems. In both continents, farming is carried out in earthen ponds, typically 1–1.5 m in depth, the exception being striped catfish culture in Viet Nam, where pond depth is 3.5–4 m. Farmer's perspectives across both continents on the future of aquaculture is surprisingly similar. Farmers in both continents are mindful of aquaculture becoming increasingly marginalized due to rapidly rising feed costs, shrinking land and water resources, and changing opportunity costs, and thus they seek careful guidance to secure sustainability.

Africa, unlike Asia, does not have a significant aquafeed industry, and therefore most farms rely on farm-made feeds and fertilizers. Some commercial aquaculture is evident in Ghana, with feeds imported from Europe, Asia and South America. Although data from Egypt are unclear, Egypt appears to be an exception, where economies of scale have created an opportunity for such development. The number of aquafeed mills in Egypt increased from five in 1999 to 31 in 2009, producing an estimated 420 000 tonnes of aquafeeds. The feed supply chains have been discussed.

In Ghana, extensive to semi-intensive farming practices predominate, with brans from rice, wheat and maize and groundnut waste used as major feed ingredient inputs. These ingredients are similar to those used in Asia, where challenges faced by farmers in securing feed ingredients are similar, as they basically all rely on procured agricultural by-products. In China, although integrated farming is practiced, this is still dependent on procured feeds. Despite the significantly higher use of commercial feeds in Asia for tilapia, catfish and carp, extensive farming using fertilizers is still prevalent, although the shift towards semi-intensive farming is evident, warranting a greater use of commercial (mainly sinking pellets) and farm-made feeds. This combination is used by farmers on both continents to cap production costs and to mitigate against unpredictability in feed supplies. Commercial feeds are relatively expensive in both continents when compared to Europe. Since 2006, commercial fish feed imports into Ghana have increased from 22 to 520 tonnes (2009), with a price range of USD0.7–1.8/kg. Nationally produced feeds in Asia range from USD0.6–1.5/kg.

Feeding is predominately undertaken by hand dispersal, although in some instances a range of devices from simple demand feeders to staked pierced feed bags are used to feed fish. For shrimps, feeding trays are commonly used. The principal index used to evaluate feed utilization is the eFCR (economic feed conversion ratio). The reported eFCR using farm-made feeds in Africa and Asia ranged between 2 and 5.

That for imported feeds, however, ranged from 1.2–2 across both continents, and as such is comparable to many parts of Europe. However, the variability in eFCR between farmers is significantly greater than in Europe, eluding to poor feed utilization and perhaps poor feeding strategies. The interpretation of such data for both continents is discussed.

Invited Reviews and Presentations

On-farm feed and feeding management strategies in tropical aquaculture

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The status of tropical aquaculture feed and feeding management is subjected to thorough reviews by various authors (e.g. Tacon and De Silva, 1997)[11]. More recently, Hasan *et al.* (2007)[12] conducted an extensive review of aquafeed management entitled "Study and Analysis of Feeds and Fertilizers for Sustainable Aquaculture Development" which addressed issues at the global, regional and country levels. Due to high feed cost during grow-out, most of these reviews are focused on the feed and feed management practices at this period of the production cycle.

In this paper, aquaculture is defined as the farming of aquatic organisms by controlling at least one stage of the life cycle. The life cycle controls are conceptually divided into larval, nursing, grow-out and broodstock management stages. At each stage, there are different feeding objectives. The feeding objectives of the first feeding larval stage are to wean fish larvae onto dry feeds while ensuring maximum survival rates. The farmers' strategies include the use of green water larval culture, either by fertilizing fish ponds or by culturing phyto/zooplankton in tank systems, or feeding fish larvae initially with live feed and subsequently weaning them onto dry feeds. The feeding objective during the nursing stage is to culture the postlarvae at relatively high densities to produce high-quality seed. The feeding strategies at the nursing stage are species specific but generally consist of green water technology for omnivorous fish or feeding fish with farm-made or commercial feeds without negatively impacting water quality. The carrying capacity at the nursing stage is mainly determined by the water quality parameters. The main feeding objectives of the grow-out stage are to reduce FCR, hence feed cost, and minimize feed/metabolic waste generation. Farmers may use either farm-made, semicommercial or commercial feeds. Widely used feeding strategies in the grow-out stage are feeding fish at: (1) 80–90 percent satiation (e.g. cage culture), (2) every other day (e.g. seabass pond culture), (3) a high feeding rate for a number of days followed by a low rate for a number of days (or a variation of this strategy; e.g. *Pangasius* catfish), (4) mixing green water technology supplemented with formulated feeds (e.g. Nile tilapia pond culture) and (5) microbial floc technology (e.g. penaeid shrimp culture). The feeding objectives for broodstock management are to stimulate the development of good quality eggs to enhance hatching and larval survival rates. Since the nutritional requirements, especially fatty acid requirements, of freshwater and marine fishes differ, different feed mixtures and feeding strategies are used by farmers. The challenges for broodstock feed preparation are species-specific. Since information on the nutritional requirements of broodstock is scarce, suitable commercial feeds for the maturation of marine fish are not widely available. Low-value/trash fish-based on-farm feeds dominate in this sector. Farmers producing seed of low fecund fish such as Nile tilapia face the problem of enhancing egg output.

The price of traditional fish feed ingredients such as fishmeal, soybean meal and cereal-based brans follows a gradual and persistently increasing trend, and hence both farm-made and commercial feed prices closely follow the flow of ingredient prices. Antinutritional and antistimulant factors prohibit the use of a higher percent of the less expensive ingredients in fish feeds. The feed cost of semi-intensive to intensive fish culture ranges from 30 to 70 percent of the farm-gate price of the fish, and in the event of husbandry

[11] Tacon, A.G.J. & De Silva, S.S. 1997. Feed preparation and feed management strategies within semi-intensive fish farming systems in the tropics. *Aquaculture*, 151: 379–405.

[12] Hasan, M.R., Hecht, T., De Silva, S.S. & Tacon, A.G.J. (eds.). 2007. *Study and analysis of feeds and fertilizers for sustainable aquaculture development*. FAO Fisheries Technical Paper No. 498. Rome, FAO, 510 pp.

failures due to such problems as water quality and health management issues, the farmers face bankruptcy. These issues and challenges, and the opportunities to respond to them are discussed in this paper.

An overview of tilapia feed management practices in Sub-Saharan Africa
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Tilapia is a traditional source of fish for the general population in many Sub-Saharan African (SSA) areas. However, tilapia production in SSA is relatively low, representing only about 2 percent of global tilapia production in 2007. At the continental level, Egypt was the largest contributor to African tilapia culture (83.3 percent) in 2007, while SSA contributed only 16.7 percent.

This review has considered only the SSA countries whose tilapia production exceeds 2 000 tonnes per year. These countries are: Congo DR, Kenya, Nigeria, Rwanda, Togo, Uganda, Zambia and Zimbabwe. Tilapia production in these countries represented 93 percent of total tilapia production in the continent in 2007, excluding Egypt. Moreover, tilapia production in Uganda, Nigeria and Zambia contributed 57 percent of total tilapia production in SSA. Tilapia culture in SSA has recently been growing substantially. During the period 2004 to 2007, tilapia production increased from 23 141 tonnes to 53 659 tonnes, with an overall annual growth rate of 32.6 percent.

Nile tilapia (*Oreochromis niloticus*) is the most important cultured tilapia species in SSA. Tilapia monoculture is also the most common practice, although polyculture with African catfish (*Clarias gariepinus*) and/or common carp (*Cyprinus carpio*) is also currently practiced. Integrated tilapia culture with agriculture and/or animal husbandry is also common in some SSA areas. In most instances, mixed sex tilapia is used, although all male culture is currently spreading in several SSA countries.

Tilapia culture in SSA is mainly a small-scale, semi-intensive activity, practiced mainly by noncommercial/subsistence farmers in freshwater earthen ponds. Pond sizes range from 50 to 4 000 m^2, while stocking density ranges from 1 to 4 fish per m^2. Medium- and large-scale, intensive cage culture is also practiced in a few countries (e.g. Ghana, Malawi and Zimbabwe). Semi-intensive production relies on pond fertilization and enhanced natural food. Composts, chicken manure, cattle manure or pig manure are generally applied. Both urea and di-ammonium phosphate (DAP) are also used for pond fertilization at a rate of about 20 N kg per ha per week and 8 kg P per ha per week.

Ingredients suitable for tilapia feed manufacture are available in most of SSA. However, aquafeed mills are few and commercial feed production is limited because the demand for commercial aquafeed is too low to justify industrial-scale production. Therefore commercial tilapia feeds are only manufactured in a few SSA countries (Cameroon, Kenya, Malawi, Nigeria, Zambia and Uganda). The high transport costs and quality issues with locally manufactured aquafeed force fish farmers to rely on imported pelleted feeds or farm-made feed. Therefore the cost of commercial tilapia feeds (20–25 percent crude protein) ranges from USD225 to >USD600 per tonne.

Farm-made tilapia feed is widely used in all of SSA, particularly in Nigeria, Uganda and Zambia. Feed formulations vary by season and geographical region, depending on availability and price of ingredients. Over 100 000 tonnes of farm-made feeds are currently produced annually in SSA, with reported feed conversion ratios (FCRs) ranging from 1.1 to 3.2. Farm-made feeds are mostly fed to tilapia in the form of dry pellets, formulated mash or formulated wet dough. Feeding tilapia with only cereal bran (corn, rice and wheat) is also a common practice, especially among small-scale, non-commercial farmers in rural areas who produce tilapia mainly for family subsistence.

Tilapia feeding is carried out either once or twice daily, depending on fish size and pond conditions. Manual feeding is the most common feeding method in all SSA regions. However, the use of automatic feeders or demand feeders has been successfully tested in tilapia cage culture (Ghana and Malawi).

The main constraints faced by tilapia farmers and the tilapia feed industry in SSA include the escalating price of ingredients and finished feeds, high transportation costs, poor transport and storage infrastructure, limited commercial feed production due to the low demand, the poor quality of locally produced feeds and limited research on tilapia feeds and feeding under local conditions.

In order to overcome these problems, the SSA governments should stimulate domestic feed industries by reducing or removing taxes on imported feed milling machinery and basic feed ingredients, provide loans to producers at low interest rates, ensure feed quality and safety through inspections and feed certification, promote the adoption of appropriate feed manufacturing guidelines and standards, provide the necessary extension services and training on the best feeding and fertilization practices, develop country-specific farm-made feed formulations and promote research on tilapia nutrition and feed management with an emphasis on nonconventional feed ingredients. On the other hand, commercial feed producers should produce and market necessary feedstuffs to fish farmers, provide high-quality feeds at reasonable prices, make proximate analyses available to clients and provide information on feed availability and efficacy to the public sector.

On-farm feeding and feed management of tilapia aquaculture with special focus on Malaysia

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A field survey was conducted over a period of 10 months in 2007 to collect data on tilapia farming practices by small, medium and large producers in Malaysia, focusing on on-farm feed management practices and feed inputs. A total of 104 farms in both Peninsular and East Malaysia from the states of Negeri Sembilan, Pahang, Perak, Penang, Sabah, Sarawak, Selangor and Terengganu were surveyed. Based on the survey, the major tilapia culture systems are in earthen ponds (64 percent), followed by cage culture (32 percent) and ex-tin mining pools (24 percent). The dominant tilapia strain farmed is the red hybrid tilapia of various varieties. The farm owners are predominantly male (age range between 41 and 60 years), and about 70 percent listed aquaculture as their major source of income. About 54 percent of the farmers own the land, but these are mainly small- and medium-scale producers. Large producers in certain states were found to operate on temporary operation licenses issued by the state land office. Tilapia production usually occupies a small percentage of the total land available on the farm, and other agricultural activities such as livestock and vegetable farming are sometimes carried out to supplement farm income; however, in some instances about 76 percent of farm land remains underutilized. Production function analysis suggested that cage culture was the best-performing system with the highest production yields. Feed costs accounted for more than 50 percent of the production costs, with the cage-culture systems registering feed costs of 66.7 to 71.8 percent of production costs. In over 90 percent of the farms surveyed, the high production costs were caused by the use of commercial tilapia feeds. The three major commercial aquafeed brands used by tilapia farmers were Cargill (33 percent), Star Feeds (30 percent) and Dindings (21 percent). Analyzed proximate composition of various feed samples mostly tallied with the composition declared by the feed manufacturers. Supplementary feed inputs such as cattle and poultry pellet feeds, farm-made feeds, copra meal, palm kernel cake, poultry intestines, animal carcasses and kitchen wastes are used by noncommercial small and medium producers to reduce feeding costs. Farm-made feeds varied greatly in their proximate composition depending on ingredients used. Inorganic commercial fertilizers for pond water fertilization are not commonly used in tilapia farms in Malaysia. The average period of tilapia culture of the surveyed grow-out farms was over 180 days. In conclusion, the technical aspects of tilapia farming such as the use of cost-effective feeds and improved tilapia strains need to be given special emphasis in terms of increasing production and maximizing profitability. Other constraints and recommendations to increase tilapia production in Malaysia are discussed.

Feed management of the major carps in India with special reference to feed management practices adopted by farmers in Tamil Nadu, India

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In India, the major carps, namely catla (*Catla catla*), rohu (*Labeo rohita*) and mrigal (*Cirrhinus cirrhosus*) dominate aquaculture production. Although Chinese carps such as the common carp (*Cyprinus carpio*), grass carp (*Ctenopharyngodon idella*) and silver carp (*Hypothalmichthys molitrix*) are also cultured, their popularity in the market (particularly that of silver carp) remains low. In some of the emerging commercial culture systems, Chinese carps are almost excluded due to marketing and other management constraints. Due to nonavailability of compound feeds, the majority of farmers in most parts of the country continue to depend on the traditional mixture of rice bran and oil cake as the common supplementary feed. Even when compounded feeds are used, the application of organic manures and inorganic fertilizers to produce natural food is widely used. Interestingly, with the increasing commercialization of carp farming and greater market focus, the commercial viability of using pellet feeds is now being addressed by feed companies; and with a number of innovations made by farmers in evolving suitable culture practices and feeding methods, pellet feeds are gaining acceptance in many parts of the country.

Despite farmers' desire to adopt compound pellet feeds in carp culture, the highly dispersed nature of carp farming suggests that there are problems in obtaining cost effective feeds in sufficiently small quantities. Due to the practical difficulties involved in obtaining compound feeds at an affordable cost, farmers are often left with no option but to continue using rice bran as the major feed input, along with some additional oil cakes. This is certainly the case in states such as Andhra Pradesh, where carp culture is well organized. In Punjab, a feed manufacturing factory is located within the state, and with a competitive price and marketing of a pellet feed, the use of compound feeds is gaining popularity with the majority of farmers. In Tamil Nadu, in areas where water availability is not a constraint, carp farming has gained popularity, and farmers have also begun to realize the benefits of feeding compound pellet feeds. Nevertheless, the availability of floating pellets and the delivery of feed to farmers are major constraints currently hindering the expansion of compound pellet feed-based carp culture in the country.

In this review, an attempt has been made to present the general feeding strategies adopted in different parts of India, with specific examples drawn from the state of Tamil Nadu, where farmers have realized the benefits of using floating pellets. The review also covers the current status of feed ingredient availability and the feed manufacturing industry and outlines the strategies that need to be developed to promote the adoption of compound feeds. Issues related to the innovations made by carp farmers in Andhra Pradesh and their adoption in other parts of the country, support for the establishment of feed industries and the establishment of mechanisms for efficient marketing and distribution of feeds are also discussed.

A review of farm feeding practices for North African catfish in Sub-Saharan Africa

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This review considers feeding practices for North African catfish, *Clarias gariepinus,* in Sub-Saharan Africa (SSA). Clariid catfish production in the subcontinent is increasing exponentially and particularly in Uganda. Semi-intensive pond culture is still the most prevalent production system, while intensive tank culture is becoming more popular in peri-urban areas in Nigeria. Total production in these two countries now exceeds 71 000 tonnes per annum.

Catfish are now commonly spawned and their larvae reared in hatcheries for 10 to 14 days, where after they are reared in nursery ponds or in tanks. Extensive rearing of larvae, after yolk sac absorption, in ponds is now less often practiced than in the past. This technology, where it is still practiced, depends mainly on adequate fertilization schedules. Feeding practices in hatcheries are closely matched with the physiological and endocrinological ontogeny of the fish. For optimal survival and growth, live food, mainly *Artemia*, is required for the first 5 d after the start of exogenous feeding, where after the fish can be weaned onto a dry starter feed. Up to a size of 5 g, the species has a high protein demand (>50 percent).

Extensive farming of catfish in ponds is largely a subsistence activity and is practiced mainly in polyculture with tilapia that serve as fodder fish and using a single ingredient feed such as maize or wheat bran. Semi-intensive on-growing of catfish in static and flow-through ponds, as well as under high-density tank culture conditions requires a complete feed. Production levels in these three systems range from 15-24 tonnes/ha/ cycle, to 40 tonnes/ha/cycle to 385 kg/m^3 per cycle, respectively. Results show that floating extruded pellets with a protein content of 30–35 percent are preferred by farmers. The duration of the grow-out cycle depends on the size of fish required by the market. At temperatures between 26 and 28 ^oC, the fish can be grown from 1 g to 800 g in seven months. Feed conversion ratios are size dependent, and best ratios are obtained by feeding the fish to satiation while observing their feeding response. Daily ration tables serve largely as a guideline. In ponds, the fish are fed two to three times per day, while under high density tank conditions, they are fed five to six times per day. During the early juvenile phases (1-24 g) FCRs are commonly <1:1 and from 25 g to 800 g, FCRs of 1.2:1 are achievable. There have been significant advances in feed availability and quality in the region, particularly in Uganda, although it would appear that weaning diets and starter crumbles are still being imported.

Shrimp feed management: issues and perspectives

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Shrimp aquafeed management aims at making available to the animals the best quality formulated aquafeed in the proper amounts and at the right times and locations. Feeding methods and techniques are as important as feed quality and are closely interlinked and interdependent. Feeding practices must be continually modified and adapted to account for natural and induced changes in feeding activity and preferences as the animals grow and/or environmental conditions change. Knowledge of shrimp behaviour and feeding habits and a continuous feedback on pond environmental parameters and shrimp population are factors critical for successful feed management.

Management of formulated aquafeeds is a sequential process that is only as strong as its weakest link. As it did some 30 years ago at the dawn of the industry, it still includes feed selection, handling and storage, feed application methods, feeding regimes, and adjustments to feeding rates. Often, observed differences in performance between different feeds are the result of the management received and not of the formulation, ingredients or manufacturing of each. If not properly managed and fed, the best formulated aquafeed will generally be not much more than expensive fertilizer.

Adequate feed management methods are critical for efficient production and to minimize environmental impacts. Shrimp production systems and their feed management must be considered together and require an understanding of biological aspects of the targeted species, of chemical and biological processes that control water and bottom quality, and continuous system monitoring and feedback to provide appropriate and timely inputs and adjustments. Effective practices will produce maximum shrimp growth and survival concurrent with the lowest feed conversion, with minimum impact on effluent quality. Inadequate feed management will lead to suboptimal production, can promote the onset of various diseases and can lead to water quality-related problems. Several sequential steps are involved in proper feed management: feed selection; reception, storage and handling; application methods; and feeding regimes.

When to feed requires determining shrimp activity patterns, feeding frequency and time (subject to change with geographical location, species, age, size, stocking density, season, unusual environmental conditions and other stimuli). Calculating feed rations involves estimating survival, population size and biomass, size distribution and natural food availability. Adjusting feed input involves population sampling and monitoring of various water parameters. Proper feeding strategies must consider physiological processes that affect feed intake and digestion in the targeted shrimp species. These include relationships between feeding activity and circadian rhythms, gastric evacuation times, molting cycle stage and others.

Shrimp are bottom feeders, and it is difficult to estimate feed consumption rate unless feed trays or lift nets are used. For many years, trays have been the best tool available to manage and adjust feed inputs and prevent under- and overfeeding. Inefficient management methods commonly include inadequate handling and storage practices for both bulk feed storage at farms and after feed distribution to the pond side for daily feedings. Ineffective practices often include applying feed during times convenient for employees but not necessarily at the best times for the shrimp, and underestimating the importance of proper training, remuneration and motivation of feed management personnel.

Areas of priority for further research include: (1) improving knowledge of biological and chemical processes in production systems which affect animal behaviour, including feeding; (2) improving knowledge of physiological processes that affect shrimp feed intake and digestion; (3) maximizing the use of natural productivity, nutrient recycling and retention in the shrimp flesh; and (4) optimizing the overall management of production systems, of which feed management is only a component in a sequential and additive process from stocking to harvest.

The development and use of compound aquafeeds has been a major factor in the successful expansion of shrimp farming globally, and efficient feed management is critical to maintain and improve the industry's financial and environmental viability. There is still much potential to improve and optimize responsible and efficient feed management practices that can be species, area and even season-specific, to optimize production efficiency, minimize environmental impacts, promote maximum biosecurity, and promote cost-efficiency and profitability.

Phase-to-phase feeding programmes must be designed to target for the best feed nutrient profile and feed presentation at a specific culture stage, environmental and rearing condition. Culture challenges such as diseases, poor water quality and high stocking densities can be minimized with the proper feed design. On the other hand, feeds must be aligned to account for the availability of natural food in ponds in order to spare critical and expensive nutrients such as proteins, vitamins and minerals.

Improving feed use efficiency of striped (tra) catfish in the Mekong River Delta, Viet Nam: farmer initiatives of adopting scientific findings

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Intensive pond culture of tra (striped) catfish was introduced to the Mekong River Delta in 1981–1982. In 2000, the seed production technologies were perfected, and the sector started to grow rapidly. Initially tra catfish farmers used farm-made feeds; however, since 2004, they have started to use manufactured pelleted feeds (MPFs). Typically, the feed costs associated with tra catfish pond culture production account for between 76.2 and 82.5 percent of the total production cost. In order to maximize profits, it is necessary to maximize feed use and efficiency. In 2008, production trials were undertaken to optimize feed use and develop better management practices (BMPs). The trials were undertaken as a collaborative effort with a number of farms in the Mekong River Delta and under the guidance of scientists from the Network of Aquaculture Centers in Asia-Pacific (NACA). A total of 51 pond trials comprising 21 ponds in the first production cycle and 30 ponds in the second production cycle were undertaken. Three feeding scenarios were tested *viz* two feed rounds per day (this is considered the conventional feeding paradigm and was considered the control), one feed round per day and one feed round every two days. Satiation feeding was applied to all groups. Feed conversion ratios (FCRs) and cost savings were calculated for the three feeding scenarios. The results demonstrated the potential to use feed management practices to improve FCRs and reduce production costs. Both test cycles demonstrated that the culture period (from stocking to harvest) of fish fed twice daily to satiation was on average 180 d, equating to approximately one month shorter than those observed with the fish grown under the alternative feeding regimes (averaging between 210 and 225 d to harvest). The FCRs obtained from the fish that were fed to satiation once per day and those that were fed to satiation once every two days were 1.60 and 1.58, respectively. These FCRs are lower than the FCRs obtained from the fish that were fed to satiation twice daily (FCR=1.65). The results suggest that feeding the fish to satiation once per day is the most efficient feed management technique. Subsequently, this intervention has been adopted by a number of farmers in the region. The adoption of this finding brings

not only economic benefits to the famers but also reduces the farm's effluent streams.

On-farm feeding and feed management: perspectives from the fish feed industry
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The growth of global aquaculture and its development from small to large scale across a wide range of species is well documented. As the global human population grows and logistics improve, the demand for seafood (wild and farmed, fresh, processed and frozen) is forecast to grow further. Seafood is healthy as part of a balanced diet, and eating seafood is also associated with a decrease in life-style diseases, which has led to professional recommendations to eat yet more.

It is clear that aquaculture will have a major role in meeting this demand for seafood. But in satisfying this demand, there must be a further shift from extensive to intensive-scale operations. For a variety of practical reasons, this intensification will mean a change from using waste or farm-made feeds to commercially manufactured pellets for fish and crustacean farming.

Commercial fish feed companies are best placed to provide such formulated pellets, but there is strong pressure to optimize the use of resources while providing the lowest cost of production to the farmer. Formulated feeds cannot compete with farm-made feeds on unit price. However, nutrient composition and technical properties should be superior in commercial feeds, and this will have an important impact on production efficiencies. Feed companies have a strong responsibility to manage and develop these properties so that feed delivered has the potential for maximum output (growth, survival, quality, efficiency). However, on-farm feed storage and management is critical to maximizing returns.

Storage at farm sites must be sufficient to maintain the delivered feed quality – dry and secure, for example. Feed management is the responsibility of the farmer. On the day of feeding, the feed used should fit the species and size of animal. The amount of feed given should be controlled and distributed evenly and effectively across the culture unit to allow feeding opportunity to all animals. Feed delivery should also be changed according to environmental conditions (e.g. diurnal water quality fluctuations). Farmers must feed with particular attention to the health status and appetite of the fish/crustaceans. Feed companies should be in a position to advise the farmers on best practice and help farmers to monitor their performance – especially if this use of manufactured feed pellets is new (e.g. feeding tables, size change recommendations). This process can be assisted by other resources such as trainers, local government schemes and development aid projects.

The benefits that accrue from the use of formulated quality feed are best achieved when the farmers optimize their management practices. Close collaboration and long-term partnerships between feed companies and farmers are strong tools to ensure efficient production and the best use of resources in the growth of healthy and nutritious aquaculture species.

Control of feed intake, feeding strategies and feed management practices with special reference to salmonids
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Under all aquaculture conditions, feeding practices have economic, environmental and social implications. Even with nutritionally adequate and balanced "environmentally friendly" feeds, inappropriate feeding practices can lead to significant feed losses causing adverse effects on water quality and a decrease in the sustainability of the aquatic animal production system. Much progress has been made in the production of salmonids through improving the nutritional value and physical characteristics of feeds, and through improved feeding methods and practices that optimize feed and nutrient utilization and reduce potential environmental impacts. There is strong scientific evidence to show that feeding systems and strategies should give due consideration to behavioural rhythms and the nutritional quality of the diets. There are currently a number of sophisticated feed distribution systems for use in salmonid production; their efficacy

is dependent upon how well they are adapted to the species, the size of fish and the culture site. There are also a number of devices to monitor the feeding activities of salmonids. Modern feeders and feeding schedules developed by feed manufacturers are based on fish size, water temperature and the energy content of feed, and provide appropriate guides to achieve maximum growth and feed utilization under diverse environmental and culture conditions.

With respect to feed processing technologies and on-farm feed management practices and strategies, it is evident that most of the progress that has been made with salmonids can be adapted and applied to other temperate marine finfish, as well as to tropical species that rely totally on man-made feeds. There is accumulating evidence to show that other marine finfish species grown in cages or tropical fish reared in ponds can adapt themselves to demand feeders. Such devices also hold promise for understanding the specific feeding rhythms of new species and for obtaining quantitative data on the control of voluntary feed intake as affected by dietary nutrients. Knowledge gained and achievements made in the development of nutritionally wholesome starter feeds, continuous feeding by using belt-feeders for rearing larval or juvenile fish, the application of bioenergetic principles to develop feeding tables and the use of extruded feeds can and should be applied to tropical aquaculture species.

Environmental consequences of feed quality and feeding management
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Poor feed quality and poor feeding strategy have major influence on environmental impact from shore-based and open-water farming systems. Excess nutrients not utilized by the fish or shrimp are released into the environment and have to be assimilated or accumulate.

Factors affecting poor utilization of feed resulting in poor feed conversion ratio (FCR) include the quality of feed (dry or moist) and the feeding strategy. The quality of the dry feeds is influenced by the digestibility of the ingredients, suitability of the formulation to individual cultured species and season, stability of the pellets in water, storage and handling of the feed, and whether the feed is extruded or pelleted.

The quality of wet/moist feed is influenced by quality, storage conditions and whether trash fish/low-value fish is fed whole or cut up, as this influences the leaching of nutrients into the environment before feed is eaten. In addition, there are risks of disease transmission.

The greatest influence on the amount of excess nutrients entering the environment is through the adoption of poor feeding strategies by the farmer, leading to overfeeding. The farmer can improve FCR by providing the correct feed amount and controlling the feeding duration, feeding frequency and timing of the feeds.

In pond culture, much of the excess nutrients are either utilized by primary production or accumulate on the pond bottom. However, nutrients are released into the environment during water exchange and at harvest time when pond water effluent is released to the environment as a point source release. In contrast, in cage and pen culture, water is passing through the nets freely and the distribution of the nutrients is highly influenced by the hydrodynamics of the site location. The excess nutrients are released into the environment in two forms, dissolved nutrients and particulate nutrients. Dissolved nutrients are typically quickly dispersed and utilized by bacteria, phytoplankton and zooplankton. However, if there are high levels of nutrients released on a continuous basis, then this can lead to eutrophication and/or algal blooms. Particulate nutrients settle and are assimilated by sediment benthos flora and fauna. If particulate nutrients are in excess of the assimilation capacity, then they accumulate, altering the biodiversity and in extreme cases causing anoxic conditions devoid of life in the sediment and the smothering of nearby sea grasses and corals.

The presentation describes a case study of the impacts of fish culture in Bolinao, the Philippines and the affects of poor feed quality and feeding strategy on the environment. It describes the aquaculture production in the enclosed bay and the environmental impact that it causes. It also describes the possible

methods for mitigation, which include improved feeds, feed quality, the prevention of overfeeding, and mixing fed species with unfed (extractive) species using integrated multitrophic culture.

Economic, regulatory and legal review of aquaculture feed management practices
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An economic analysis of feed management practices was undertaken for an intensive land-based recirculating marine finfish farm culturing the South African dusky kob (*Argylosomus japonicus*). A bio-economic model was developed to describe the economic efficiency of the farming operation under variable production scenarios. The model was used to interrogate the effect that feed management practices have on the economic viability of the production system, and a sensitivity analysis was undertaken to establish the effect that feed type, cost, feed conversion and growth have on the economic viability of the farming operation.

An analysis of the legal and regulatory frameworks that have been developed to optimize feed management practices and reduce the negative environmental impacts that accrue to poor feed management is presented. To date, such frameworks include: (a) establishing minimum feed performance criteria (e.g. FCR, nutrient digestibility), (b) placing restrictions on nutrient composition in formulations (e.g. nitrogen and phosphorus levels), (c) restricting feed use, (d) restricting environmentally unsustainable feeding practices and (e) promoting best management practices and codes of conduct to improve feed management practices. In many production systems, feed management affects the quality of a farm's effluent streams, and thus regulatory frameworks focusing on the monitoring and control of effluent streams may also indirectly impact on feed management practices. Such regulations include: (a) treatment regulations to treat effluent streams prior to discharge, (b) limiting the quality and or quantity of effluent that can be discharged, (c) limiting farming activities in an area based on effluent carrying capacities/dispersion and (d) promoting best management practices and monitoring protocols to manage effluent streams. The efficacy of introducing these legal and regulatory frameworks to improve feed management practices is discussed.

Feed management in small-scale aquaculture in the Asia-Pacific
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The main feed management practices that are available to small-scale farmers are associated with overfeeding, the use of feeds that may be of higher quality (e.g. of higher protein content) and hence more costly than desired or needed in tropical systems, and a lack of attention to the possibilities of adopting simple but effective methods that could reduce feed costs, such as the use of "mixed feeding schedules". Also note has to be taken of increasing efforts of vested interests to popularize commercial feeds among farmers on the pretext of environmental concerns and the like that are often unproven scientifically.

In the Asia-Pacific region in particular, farm-made/semicommercial feeds constitute a significant proportion of the feeds used in finfish farming systems. However, this sector has been relatively neglected and limited with regard to R&D. Improvements to this sector, made in the preparation of such feeds could reduce feed costs and enhance economic efficiency. There is a need to evaluate the quality of such feeds in relation to equivalent commercial feeds in order to provide scientific evidence on the type of feed that is most economically efficient and to counteract perceptions that the latter feeds are better and more suitable.

In feed management in tropical semi-intensive finfish farming, there is increasing evidence that the use of mixed feeding schedules is economically and environmentally beneficial and does not impact on the performance of the stock or the product quality. Further farmer adoptions of these feed management methods should be encouraged, and the emerging on-farm results of the use of these methods should be widely and effectively disseminated.

The FAO Expert Workshop on "On-farm feeding and feed management in aquaculture" was convened in Manila, the Philippines, from 13-15 September 2010. The workshop was organized with three objectives: a) to review and analyze the existing knowledge on the application of feed management as a tool for reducing feed costs in aquaculture, b) to identify the major issues and constraints of feed management and those that need to be addressed and c) to prepare a list of recommendations to define/suggest the future course of action including the preparation of technical manuals/guidelines for dissemination to farmers. The workshop consisted of technical presentation and working group discussion. The technical presentations included invited reviews, case studies and synthesis of the case studies. Following several working group deliberations, and a general plenary discussion, the participants identified seven primary issues that currently constrain feed use and management in aquaculture, namely: 1) limited access to information on feed and feed ingredients (availability, prices and quality); 2) poor feed preparation, processing, handling and storage at the farm level; 3) inadequate monitoring of feed and farm performances; 4) low impact of current dissemination strategies on improved feeding and feed management; 5) gaps in the understanding of the economic aspects of feed management; 6) health aspects and their implications on feed management; and 7) feed quality – lack of regulatory mechanisms. A comprehensive set of recommendations was developed to overcome the constraints that were identified and it is anticipated that these recommendations will guide the FAO's future work in this arena.

ISBN 978-92-5-106713-0 ISSN 2070-6987

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I1915E/1/01.11