

Part A – Consolidated report and synthesis of the project findings¹

EXECUTIVE SUMMARY

Three strategic outlooks guided the methodological approach of the project. The first was to understand the roles of the immediate stakeholders of the marine cage culture industry – fishers and traders of low-value fish, farmers, and feed manufacturers – in the pursuit of the main objective of the project; the second was to treat the transition to commercially formulated feeds as a process of adopting a package of technology rather than the use of an alternative material input; and the third was to study the technical, economic, environmental and social constraints to the transition to commercial pellet feeds. Part of the social component of the project was an assessment of the possible impacts that a transition to pellet feeds would have on the livelihoods of the fishers and suppliers of trash fish/low-value fish.

The context of this regional project was defined by two regional trends in the marine aquaculture sector in Southeast Asia and Southern China and one global concern. These are (i) the increasing production in high-value carnivorous marine finfish, (ii) the decreasing supply of low-value aquatic animals that are extensively fished and used as feed for the cultured fish, and (iii) the increasing global concern over the use of fish to feed fish. The first and second issues highlight two problems, namely, a growing shortage and rising cost of trash fish/low-value fish, and the likely over exploitation of the fishery resources. The third is a potential trade problem arising from an ethical issue. This issue may not be wholly addressed by the use of pellet feeds in which the main protein and lipid sources is fishmeal and fish oil respectively. The switch however would increase the efficiency of feed (and therefore fish as feed) utilization. Nonetheless, these three issues collectively serve as the justification for the overall objective of the project, which is *to reduce the reliance of cage culturists on wet fish as a direct source of nutrition for their stock, and move them towards the use of commercial feed formulations.*

The project found that the farmers who have been using commercial feed formulations solely or in combination with trash fish/low-value fish tend to better understand the linkages between profitability and good feed management. This affirms the technical justification for the corollary objective of the project, which was *to improve the farm management practices of farmers* regardless of the feed they were using. The received wisdom from agricultural technology diffusion studies is that a better farm manager is likelier to adopt a technological innovation earlier.

The broader perspective adopted by the project is that a commercial feed formulation is part of a new technology package - rather than a more efficacious material, and this is reflected by its having technical and economic, environmental and social components. These are described briefly as follows:

- The technical component comprises the on-farm trials using farmers' standard practices and supervised by the technical personnel of the project. It compared the technical and economic efficiencies of pellet feed and trash fish/low-value fish and demonstrated the possibility of using pellet feeds in marine fish farming, and especially on grouper farms, where the farmers have well-entrenched attitudes towards the use of trash fish/low-value fish and are sceptical of pellet feeds.

¹ Part A of this technical paper has been prepared by Mr Pedro B. Bueno and Dr Mohammad R. Hasan.

- The environmental component compared the biological and physical impacts of trash fish/low-value fish and pellet feed on the water column, and the bottom sediments in the immediate culture area, the amount of embodied energy required to produce a kilogramme of fish, and the amount of fish needed to produce a kilogramme of fish (fish-in fish-out ratio, or FIO).
- The social component comprises three aspects: an assessment of the livelihood assets and options available to fishers and traders of trash fish/low-value fish, and their perceptions of the potential impacts that a wholesale switch by the farmers from trash fish/low-value fish to pellet feed would have on their livelihoods. An assessment of the perceptions and attitudes of the fish farmers towards the use of trash fish/low-value fish and pellet feeds before and after the farm trials, and an assessment of farmers' perceptions of their access to, and use, of credit for capital and operational expenses including the purchase of pellet feeds. Attached to the farm trials and the farmers' post-trial perceptions were a series of assessments of the farmers' knowledge of the attributes of pellet feeds, their access to supply, and the feed manufacturers' perspectives on the issues.

The relevant findings are:

- Farmers do not always have good access to pellet feeds, and while trash fish/low-value fish is more readily available, and its price is increasing, it is still generally cheaper than pellet feeds.
- Farmers are aware that those pellet formulations that are available, apart from those produced specifically for some species, are not specific to the species or the growth stage of the stock so that they use cheaper or less suitable substitutes resulting in poorer FCR.
- Many farmers have been using a combination of pellet feeds and trash fish/low-value fish, i.e. pellets for small fish and trash fish when fish are larger,
- Feed management is generally poor, and is given less attention than health management by the farmers.
- Accessing seed of the desired culture species is a general problem - more so in Thailand and Viet Nam where supplies are unreliable, or of poor quality, or both,
- Diseases cause significant reduction in profitability in China, Indonesia and Viet Nam, while influx of freshwater into the estuaries where cages are sited causes massive mortalities in Thailand.
- Cash flow does not match, or credit is inadequate, for the capital outlay needed to purchase pellet feeds.
- Feed manufacturers are hesitant to produce a feed that is tailored to a species that is not being produced in enough volume to create an economy of scale - with the exception of humpback grouper in Indonesia, cobia in Viet Nam and barramundi in Thailand.

A follow-up mission to Indonesia, Viet Nam and Thailand that was undertaken 16 months after the end of the farm trials found varying levels of uptake of the project findings by the farmers. Vietnamese farmers had begun trying pellet feeds; Indonesian farmers were hesitant to use the results of the trials on brown-marbled grouper for their preferred species, humpback grouper; Thai farmers found accessing pellets difficult. An encouraging finding was that all the farmers would switch to pellet feeds if suitable formulations and sizes were available. An issue shared by the Vietnamese and Thai farmers was the lack of quality seed. Access to capital remained a prominent constraint to the uptake of pellet feeds, and farm expansion. Finally, a business case, drawn from the potential market for grouper feed in Indonesia, can be made for the production of species-specific feeds.

To place these findings in the context of the project objective, access to feed, seed, and operating capital are technical constraints associated with a lack of inputs. Poor feed management and disease control are operational problems exacerbated by the lack

of proper technical and management guidance. The lack of suitable pellet feeds in the market is first and foremost a business issue. In this regard, research on the nutritional requirements of specific species and use of alternative low-cost ingredients may help feed manufacturers develop suitable formulations. Research on alternatives to fishmeal has in fact been intensified, especially in Europe, but the projects are mostly geared to salmon and other species, and none or hardly any research has been undertaken on groupers. However, some of the results could be used by Research & Development (R&D) institutions in Asia-Pacific to develop specific feeds for species that are cultured in the region. Policy incentives to promote technology development and for the manufacture of feeds that are specific to mariculture species in Asia could facilitate the commercial production and marketing of the products. Meanwhile, feed manufacturers may consider organized farmer groups as part of the feed supply chain to which the usual distributor or retailer discounts could be granted.

The assessments found that the attitude of most farmers is generally favourable towards the use of pellet feeds; prior to the trials, some had been using them, and others have seen the possibility of their use from the farm trials. These findings suggest that the key to adoption is to make the right kind of feeds available and easily accessible. Everything else supports the farmer's decision to adopt the feed. After adoption, there is a need to reinforce the farmer's decision so that he or she does not revert to using trash fish/low-value fish. The supporting elements would be technical advice on better management practices, enabling ready access to operating capital with timely cash flows, or the provision of commercial loans on favourable terms, enabling the purchase of feed at discounted prices (through bulk buying, for instance), providing the right motivation for farmers to organize, and sustaining technical advice through extension. A major assistance would be to encourage and facilitate the organization of farmers' associations or to strengthen existing ones. The project had inspired the Vietnamese and Indonesian farmers to infuse professionalism in the programme, and to improve the operation of their existing associations. Some of the Thai farmers were beneficiaries of a government funded Community-based Enterprise Development Programme, in which contiguous farmers are participants, and are provided access to training, technical advice and small loans.

The environmental assessment showed no significant difference in the biological and physical impacts of using either feed source on the waters and sediment of the farm sites; the slight differences that were found were attributed to feeding practices and the quality of the feed used, particularly the trash fish/low-value fish. This in fact is a significant result, and it highlights the need to regulate the density of farm units to an optimal number that does not exceed the carrying capacity of the area. The finding further highlights the importance of applying appropriate stocking densities and feeding practices. The finding on site pollution, notwithstanding the statistical insignificance of the impacts, would be an important part of a better management guide. The estimations of energy usage revealed that more energy is embodied in the amount of pellet feeds than feed fish needed to produce a kilogramme of fish. On the other hand, calculations of FIFO (fish-in fish-out) showed less fish is used with pellet feeds to produce a kilogramme of fish. The comparative energy consumption can be an important issue from a global perspective. However it is hard to see how this could be incorporated into an extension message. The same might be said of the FIFO result. In the end, the pollution, energy and fish-in fish-out issues will be addressed at the farmer level by promoting the efficient use of feed and better management practices. These could be more broadly addressed through Research & Development (R&D) on alternative feed ingredients, which has been intensifying, and policy incentives for technology development and manufacture of less polluting and more efficacious feeds that uses less or no fish. The embodied energy issue would have to be part of national and global programmes to reduce the carbon footprint of the industry.

The social component of the project addressed the livelihood alternatives of the fishers and traders of trash fish/low-value fish. Its justification was that the livelihoods of fishers and traders – who have long been important stakeholders in the development and expansion of the marine cage culture sector of Southeast Asia and Southern China – are threatened by a wholesale shift to commercially formulated feeds. The findings indicate that the fishers principally target food fish which brings a higher income or, in the case of small fishers, is for home consumption. Fishers have a market for the trash fish/low-value fish in terms of the fishmeal processors, and already have or can find alternative occupations. The findings suggest that the greater threat to the fishers' livelihoods will not come from farmers ceasing to buy trash fish/low-value fish, but from the depletion of the fishery resources. The policy implications from these findings include providing assistance to the fishers that use large boats to improve their on-board preservation techniques so that they can land a higher proportion of food grade fish; in the event that policies are developed to reduce fishing capacity, there will be a need to develop alternative livelihood opportunities and training programmes, better management of the fishery resources, including the introduction of closed seasons, appropriate gears, and the withdrawal of fuel subsidies. In addition to the impact on the fishery resource, fuel subsidies fail to reflect the true market price of the fish, which in the long run, when the supply of trash fish comes to an end, would expose the low efficiency and therefore poor competitiveness of a country's cage culture industry. Furthermore, a higher price for trash fish/low-value fish may even hasten the farmers' transition to pellet feeds.

There are a number of issues that the project brought to light but did not address directly in the implementation. Foremost among these was the market and market access. The market prospects in Southeast Asia and southern China remain positive. The diminishing wild catch of, particularly, grouper, would increase demand for farmed fish. Ironically, the lack of seed stock helps to maintain high prices as the farmers cannot stock their cages. The industrial scale production of marine fish in large offshore cages has started, but is not expected to expand rapidly so that in the foreseeable future, much of the supply will still come from the inshore or near shore small- to medium-scale cage farms. The occasional natural disaster and fish kill from biotic and abiotic causes keep a check on oversupply. The growth in trade of live fish to supply the restaurant trade in Southeast Asia and southern China is not showing signs of abating, and the issue of certification is not as yet a major concern. However, an international standard on live reef food fish trade has been issued by the Nature Conservancy (TNC) and several collaborating organizations, which includes management and operational requirements for cultured live food fish. It is for voluntary adoption in the live reef food fish trade. Certification standards could be the next area of concern for farmed fish. Better management practice (BMP) guides that are developed should incorporate these standards.

Marketing issues are dependent on the species being farmed: premium species such as coral trout grouper and mouse grouper are primarily exported to southern China and China, Hong Kong SAR. Lower priced species like brown-marbled and orange-spotted groupers are raised for the local market or sold directly to seafood restaurants. Price related risks are higher for premium species that are exported and therefore have a longer market chain. In the future, assistance would be needed in terms of supplying real time market information and organized marketing. Prices in the local markets are more easily monitored, and communication between farmers and buyers can be facilitated by the cellular phone.

The marketing, credit and cash flow issues influence the farmers' decisions in terms of whether to adopt pellet feeds or continue using low value/trash fish. The lack of sufficient capital restricts a farmer's ability to buy pellet feeds. Lines of credit could alleviate this problem and ensure that there was sufficient operating capital throughout

the production cycle. In addition, increased credit and improved cash flow, would increase the farmers' ability to negotiate product prices and prevent them from being forced to sell their fish at a low price - although an inescapable bio-economic constraint is the diminishing economic returns from feeding fish beyond a given optimal size. The marketing-credit nexus has been given due attention by the project, and the general need is the provision of adequate loans on reasonable and easy terms. This becomes a crosscutting issue that has to be addressed by convincing the institutional lending agencies that the cage culture farmers are creditworthy. Creditworthiness could be linked to the adoption of better farming practices, and the farmers being organized. Lending schemes at low interest rates could be developed for organized farmers adopting BMPs.

Closely related to creditworthiness is the provision of insurance for the cage farmers. The high risk associated with cage culture would normally require a high premium assuming a commercial insurer finds the business of insuring cage farms worthwhile. As with credit, insurance could be linked to farmers being organized and adopting BMPs.

The issue that pervades the effort to effect a transition to pellet feeds, and which in practical terms promotes the adoption of technological innovations, is risk management. It would be applied to actual and perceived risks to the profitability of adopting pellet feeds, the environment, and the impacts on the livelihoods of fishers and fish suppliers. This requires an integrated approach to the development and implementation of the different instruments and risk management strategies. The risk management instruments and risk reduction strategies include the BMPs, farmers being organized, the assurance of supply and the quality of inputs including seed, feed and credit, aquatic animal health management, market based insurance, public compensation for catastrophic damage, better marketing of products, product certification, coastal zone management, and alternative livelihood opportunities. The policy, regulatory, implementing, and technical support components of these various instruments will benefit from the strengthening of institutional and human resource capacities. This in turn is facilitated and made more cost-effective by institutional and stakeholder collaboration. Regionally, these linkages are already in place in terms of national and regional institutions, the collaborative arrangements, and the mechanisms for better cooperation that already exist.

The project adhered to a unifying principle: that regional policies and programmes to encourage the adoption of pellet feeds shall equally promote the objectives of food security, poverty alleviation and the sustainability of the environment.



Preparing trash fish for marine cage fishes, Zhanjiang, Guangdong, China. Trash fish are generally minced and fed directly to the cages in this area.

Courtesy of FAO/M.C. Nandeeshan



Compound pellet feed for marine cage culture in Thailand. Commercial pellet feeds in Thailand are mostly produced for barramundi and are used for all other fishes including groupers as species-specific feed formulation for other marine fishes are not available.

Courtesy of FAO/Mohammad Hasan

I. Introduction

1. BACKGROUND AND RATIONALE

Marine finfish aquaculture is a rapidly growing subsector in Asia-Pacific and is characterized by the culture of high-value carnivorous fish species (such as groupers, barramundi, snappers, pompano) in small cages in inshore environments such as estuaries, bays and sheltered areas created by islands. The cage systems are typically made up of a wooden or bamboo frame held afloat by drums (usually plastic and sometimes with polystyrene). Nets are hung from the frames and are typically between 3 to 6 metres in length and width and about 2 to 4 metres in depth. The cage systems include a roofed building that houses workers. It sometimes includes a walkway but the frame is also used as a walk way. In clear water (low turbidity) shade cloth, either at the surface of the water or as a “roof” is used to reduce light intensity. This is thought to prevent sunburn and decrease shyness and stimulate feeding in shy species. However, there is a move towards larger and stronger cages in offshore areas in China. Species cultured in the different environments typically depends on the salinity. Traditionally wild seed stock has been used for marine cage culture, however, the hatchery technology for a number of species has been developed and commercialized to different extents in China, Taiwan Province of China, Indonesia, Malaysia and Thailand.

These high-value carnivorous fishes are mostly raised on low-value fish/trash fish¹. The total production of cultured marine (and brackishwater) carnivorous finfish in the Asia-Pacific region in 2008 was more than 600 000 tonnes, of which 75 000 tonnes was grouper (FAO, 2011). Feed conversion efficiency is poor with the use of low-value fish ranging from 7:1 to 15:1 in average grouper farming practices (De Silva and Turchini, 2009). Farmed groupers are almost exclusively raised on low value fish, which means that at least half a million tonnes of fish had gone into grouper production in 2008 and roughly in the order of 4 million tonnes overall. The expanding demand for grouper and other carnivorous marine species will further drive the expansion of mariculture. This cannot be sustained unless farmers shift to formulated feeds for the following reasons: the increasing harvest and already erratic and dwindling supply of by-catch to feed farmed fish could negatively impact the ecology of the fishing grounds, the continuing use of low-value fish could contribute to the deterioration of the growing environment, and its use as feed may not be economically sustainable. There is also the ethical issue of whether the direct use of low-value fish as a human food may be more socially desirable than feeding it to fish - given the nutritional status of the many poor people in the countries that are heavy users of by-catch that are usually harvested from their coastal waters or exclusive economic zones (EEZs). It is thus an extremely desirable goal from the social, economic and environmental standpoints to promote the transition from low-value fish to formulated feed. To achieve the transition is however fraught with complications. The first difficulty is posed by the structure of the sector: most of the marine fish farmers are independent small scale operators, the supplies of low-value fish come from a mix of small and medium artisanal fishers in Southeast Asia and fairly large commercial trawlers in China. The supply chain includes middlemen who usually forge preferential relations with the fish farmers,

¹ “Low-value fish” is used as a generic term. In specific references to the state of the material, “trash fish” is used. Trash fish/low-value fish that have a low commercial value by virtue of their low quality, small size or low consumer preference – they are either used for human consumption (often processed or preserved) or used for livestock/fish, either directly or through reduction to fishmeal/oil (Funge-Smith, Lindebo and Staples, 2005).

and the suppliers of formulated feeds have yet to make business arrangements to make formulated feeds easily accessible to the small scale cage culture farmers, as they have done for the shrimp, tilapia, seabass or pangasiid catfish farmers. The second is the lack of an operational understanding of farmers' perceptions of the comparative benefits of the use of low-value fish and formulated feeds and a scientific assessment of their farming practices and livelihood strategies. The third is the lack of organized scientific information and technical assistance to (a) persuade the farmers that it is in their immediate and long term business interests, family's livelihood, natural resources and community's interests to switch to formulated feed and (b) serve as guidelines for governments to formulate policy that include regulations and market-based incentives to make it more economically beneficial for farmers to use formulated feed rather than low-value fish.

As these issues pervade the mariculture subsector of the region, a regional project to address them was deemed a cost-effective approach; it would create synergies from the sharing of information generated by the country components of the project.

1.1 Objectives

The practical objectives of the project are to remove misconceptions among farmers on the use of alternative feed resources and demonstrate the economic and environmental benefits from their use; contribute to the development of better feed management practices in small-scale carnivorous finfish farming that improve the efficiency of feeding practices as well as market access for the farmed fish; improve the farm management skills of farmers; and provide information for policy, management and technical support that would encourage a sustained shift to formulated feeds. A social objective is addressed to the fishers and suppliers of low-value fish, and that the project would provide information to develop policies and strategies that enable this segment in the value chain to mitigate the possible impacts on their livelihood of fish farmers switching to pellet feeds.

1.2 Project framework

The development goal of the project is to contribute to the sustainability of the livelihoods of the small-scale marine finfish farmers in Asia. As such, and by minimizing the dependence on fish as a primary feed resource, it would also help in the conservation of the inshore fish resources.

The envisioned outcome is the long-term viability of finfish mariculture and improved livelihood of farmers, facilitated by support from strengthened public and private sector institutions and appropriate policy. A broader social contribution would be the improvement in the welfare of the poorer segment of the population that are directly and indirectly dependent on marine aquaculture for a living. The objectives are to be attained through eight project outputs, as follows:

1. Information on the livelihoods of people involved in the supply of low-value fish for marine finfish aquaculture purposes, the marketing channels for the input, farmers' perceptions of the use of low-value fish, and the constraints to adopting new pellet feeds as a food source for the cultured stock. This set of information is the basis for determining the approach to the subsequent activities including communicating the findings of the project.
2. Farmers' associations or "Aquaclubs" are organized and trained. These are expected to form the nuclei in each country for the wider dissemination of the project findings.
3. Scientific data collected and analysed on the technical and economic performance of small-scale marine fish farms using low-value fish and compound pellet feeds. This output includes an understanding of the constraints to the adoption of

better feed management practices and information on any changes in farmers' perceptions that occurred during course of the trials.

4. Information material, in printed and audio-visual media, in English and local languages, outlining the economic, environmental and social advantages of the use of compound feeds over that of low-value fish in small-scale mariculture in Asia. This information would be made available to the farmers' clubs.
5. Business relations are identified between organized farmers' groups and feed suppliers that can facilitate feed procurement. This output would inform a microcredit scheme for the small-scale farmers.
6. Strengthened capacity of government personnel to provide technical advice on feed usage and management in small-scale marine finfish farming systems.
7. Assessment and comparison of the environmental impacts of using low-value fish and formulated feed.
8. A monitoring system of farmers' perceptions and attitudes towards and uptake of formulated feeds and their environmental impacts is developed.



Red snapper harvested after completion of farmers' participatory cage trial in Techeng Island, Haitou Town, Xiashan District, Zhanjiang, Guangdong, China.

Courtesy of FAO/IM.C. Nandeesh

II. Project activities

Sequential and simultaneous actions were carried out to produce the eight outputs. These are described below. The major project activities were the comparative on-farm trials with the participation of the farmers, an assessment of farmers' perceptions toward the use of low-value fish and pellet feeds, the environmental impact assessment of feeding, and an analysis of the livelihood assets and options of the fishers of the low-value fish. The activities were:

1. An inception and planning workshop, organized by FAO and NACA, and with the participation of representatives of the governments of the four participating countries, farmers, fishers and the feed manufacturing and supply industry. The workshop was designed to finalize and agree on the project methodology, outputs, responsibilities and schedules.
2. Four in-country planning and awareness raising stakeholders' workshops, organized by NACA and the responsible national agency, and with the participation of representatives of farmers, fishers, traders, and feed manufacturers.
3. An assessment of the livelihood assets and opportunities of fishers and traders of low-value fish and their perceptions, carried out with a structured questionnaire that was administered in personal interviews of fishers and traders (middlemen) in the four countries.
4. Comparative participatory farmers' trials, conducted on-farm to compare the technical and economic performance of fish fed either trash fish/low-value fish or commercial pellets. The species used were: China- red snapper (*Lutjanus erythropterus*) and orange-spotted grouper (also known as green grouper) (*Epinephelus coioides*), Indonesia- brown-marbled grouper (also known as tiger grouper) (*Epinephelus fuscoguttatus*), Thailand- barramundi (also known as Asian seabass) (*Lates calcarifer*) and brown-marbled grouper (*Epinephelus fuscoguttatus*) and Viet Nam- snubnose pompano (*Trachinotus blochii*) and red snapper/crimson snapper (*Lutjanus erythropterus*). The technical performance indicators that were applied were growth rates and feed conversion ratios. The economic performance indicators that were applied were feed cost of production or cost of feed per kilogramme of fish produced. Comparisons were made in terms of feed used by the species within country and by the same species across countries.
5. Analysis of the farmers' perceptions of low-value fish and pellet feeds. This was done through a rapid appraisal in selected villages and farming clusters. A second appraisal was carried out after the farm trials to find out changes in perceptions.
6. Environmental impact assessments were undertaken to compare the effects of low-value fish and pellet feeds on the culture site, in particular the water column and the sediment beneath and in the vicinity of the fish cages. Indicators of impacts were the concentrations of phosphorous as phosphate, nitrogen forms including ammonia, nitrates and nitrates, dissolved oxygen, pH, bacterial loading and the nutrient loading in the water. The flora and fauna in the sediment as well as some physical (colour) and chemical (odour) properties of the sediment were used as indicators of its quality. Two performance indicators subsequently included in the environmental study were FIFO (fish-in fish-out) ratio and the amount of energy embodied in the feed and trash fish to produce one kilogramme of fish. FIFO provides an indication of the biomass of fish used to produce one kilogramme of fish.

7. The second set of in-country stakeholders' workshops reported on the progress of the farm trials and the environmental impact assessments and suggested improvements for increasing feed use efficacy, feed management efficiency and farmer practices. Ways to facilitate farmers' access to commercial formulated feeds, such as through discounts from bulk purchase and credit schemes, were discussed.
8. Two other activities were carried out during and after the trials: the organization of farmer clusters and the development of extension materials.
9. The final regional stakeholders' workshop consolidated the results and conclusions from the various components of the project and formulated provisional recommendations that addressed the objectives of the project.
10. A follow-up series of consultations (through on-site interviews and discussions followed by mini workshops) with participating and non-participating cage farmers, fishery officers as well as representatives from the feed manufacturing sectors were carried out in Indonesia, Viet Nam and Thailand. The purpose of these consultations was to assess the farmers' uptake of the project recommendations, confirm the findings, fill in information gaps, refine the recommendations and develop follow-up projects to address the common and outstanding issues.

III. Synthesis of project findings

1. PROJECT COMPONENTS

The project comprised four components, namely, (i) the participatory on-farm trials to compare the performance from low-value fish and pellet feed; (ii) an assessment of farmers' perceptions toward two factors, namely, the use and performance of the two feed types and their access to and preference for credit; (iii) the environmental study to determine the impacts on the environment of the use of low-value fish and pellet feeds; and (iv) the livelihood analysis of the fishers and suppliers of low-value fish for cage culture of marine fish.

The survey of the livelihood strategies, assets and options of the fishers and fish traders was carried out at the start of the project. The perceptions and attitudes of farmers toward the use of both types of feed were assessed before and after the farm trials.

An interim activity, conducted at the outset of the farm trials, was to recommend ways to sustain the participation of farmers and enhance the participation of women in the trials.

2. OUTCOMES

The envisioned long term outcome of the project was the transition from low-value fish as a source of protein for cultured fish to commercial feed formulations. Two essential shorter term outcomes were the reduction in cage farmers' dependence on low-value fish and their adoption of better management practices (Table 1).

3. LINKAGES AMONG THE PROJECT COMPONENTS

The core of the project was the participatory on-farm trials. This component was designed to provide the technical and economic evidence to persuade farmers to adopt pellet feeds. Its practical contribution was the generation of technical information from the trials, which were conducted on-farm using farmers' practices and under industry standards to improve the feed management practices of farmers regardless of the type of feed they were using in order to reduce waste, improve the efficiency of feed usage, improve profitability, and reduce the environmental impacts of the farming operation. The results of the trials also served to identify issues for further research and technology development. The report appears as Annex 1.

The second component provided two important benchmarks to the performance trials, technical and sociological. The beliefs and perceptions of the farmers on the use of low-value fish and pellet feed, as well as their access to and attitude towards microcredit, gave the researchers the opportunity to attend to the features and results of the trials that would either provide a scientific explanation to farmers beliefs or a science-based argument to refute the beliefs. The post-trial assessment of the changes in perceptions, assumed to be associated with the results of the trials, provided the basis for suggesting strategies to (a) address the reasons for a lack of change in feed use, (b) facilitate change, and (c) reinforce any positive changes that had been observed. The assessment on access to and attitudes towards microcredit was aimed at determining whether an easy and reasonable access to operating capital might ease farmers' adoption of commercial pellet feed, and if so, how access to capital could be facilitated. The result of this component is incorporated in Annex 1.

The objectives of the farm trials were complemented and reinforced by the findings of the third component, the environmental impact study. This component expanded

TABLE 1
Results and envisioned outcomes of the project

| Component | Findings | Key results | Contribution to objectives | Recommended products |
|--|---|---|--|---|
| Farmers Participatory Trials | <ul style="list-style-type: none"> Comparative technical and economic efficiencies Farmers' feed management practices Quantitative and qualitative variabilities associated with efficiencies | <ul style="list-style-type: none"> Critical factors of efficiency and profitability <ul style="list-style-type: none"> Practices Quality of feed Specificity of feed to species and size Reliability and quality of seed supply | <ul style="list-style-type: none"> Biological, technical and economic arguments for promoting the use of pellet feed Better feed management Feed manufacturers' awareness of technical constraints to adoption Improvement of breeding, seed production and supply systems | <ul style="list-style-type: none"> BMPs Technical manuals Farmers associations Capacity building programme R&D programme |
| Survey of farmer perceptions on feed type and credit | <ul style="list-style-type: none"> Technical basis of perceptions Technical and social-cultural constraints to the adoption of pellet feeds | <ul style="list-style-type: none"> Economic, social and cultural basis for changes in perceptions Attitude towards microcredit | <ul style="list-style-type: none"> Communication, extension strategy Access to credit | <ul style="list-style-type: none"> Extension materials Advisory on credit provision Crop insurance schemes (market and public) |
| Environment Study | <ul style="list-style-type: none"> Risk factors from <ul style="list-style-type: none"> feed type feed quality feeding practice Impacts of feed type on culture site Energy use by feed type Fish resource use by feed type | <ul style="list-style-type: none"> Feed quality control Feeding practice Farm management Farm siting | <ul style="list-style-type: none"> Arguments for zoning, site selection, carrying capacity study, regulations | <ul style="list-style-type: none"> BMPs Technical guides for site selection Guides for licensing and area management |
| Livelihood analysis of fish suppliers | <ul style="list-style-type: none"> Characterization of threats to traditional livelihoods Assessment of livelihood assets, strategies, and options | <ul style="list-style-type: none"> Adaptation strategy Alternative livelihood opportunities | <ul style="list-style-type: none"> Fishery resource management | <ul style="list-style-type: none"> Policy guides incentives vs. subsidies Key areas for technical and economic assistance |

its scope from impacts of the type and quality of feed and feeding practice on the immediate culture area to the broader indicators of environmental impact, namely, the amount of energy embodied in the amount of feed whether low-value fish or pellets that produces one kilogramme of fish and the amount of fish that is used to produce one kilogramme of fish (fish-in fish-out ratio). The report of the environmental impact study appears as Annex 2.

The fourth component has a socially oriented objective. The fishers and suppliers have had a major role in the development and expansion of marine cage culture sector by providing the small- and medium-scale farmers with the low-value fish to feed their high-value crop. As such they have had a major contribution to the livelihoods of the fish farming households as well as to their own fishing crew members and traders in low-value fish. A switch to pellet feeds represents a threat to the livelihoods of the fishers and others involved in the supply of low-value fish. For many of them, fishing is their major source of livelihood. The livelihood analysis would inform the formulation of strategies to enable this important group in the value chain to effectively mitigate or cope with the possible impacts on their livelihood of a shift from low-value fish to pellet feeds.

The changes in perceptions and practices several months after the trial were among the impacts of the project that were assessed by a follow-up mission to the project sites. The mission conducted interviews and meetings with trial participants and other farmers, fishery officers and feed manufacturers. This part of the mission findings is included in Annex 3.

The final regional stakeholders' workshop held after the end of the farmer participatory trials synthesized the findings and conclusions from the four components and formulated the recommendations. The workshop report appears as Annex 4.

Finally, the follow-up mission assessed the issues related to the uptake of the project findings, confirmed the priority requirements of farmers in each visited country and proposed projects to address these priorities. The report of the mission appears as Annex 5.

4. SALIENT FINDINGS

4.1 Farmers' participatory trials

4.1.1 General findings

The farm trials generally demonstrated the technical feasibility of using pellet feed to replace the direct use of low-value fish in marine finfish culture in cages. The trials suggest that pellet diets offer viable alternative for marine finfish cage culture in the long run. Although the results varied between countries because of variations in farming and management practices - the use of pellet feeds achieved similar performance in terms of growth, survival, food conversion, production and economic benefit to the direct use of low-value fish.

Generally feed type did not make much of a difference in growth or cost performance, except when low-value fish that was of poor quality was used, although the result in Viet Nam attests to the importance of using a high quality feed in obtaining better performance. Improvements in feed management practices regardless of feed type would improve feed utilization, environmental sustainability and farm profitability.

Between the countries, there were differences in the feed cost of production when pellet feeds or trash fish/low-value fish were used. The differences were primarily a result of the prevailing cost of pellets and trash fish/low-value fish in each country rather than of growth performance. Had the feed costs been the same among the countries, the economic performance would have also been the same.

Management practices, growth and feed utilization varied widely between farmers within each country and between countries. In this respect the greatest contribution to improvements in growth, feed utilization and, ultimately, improved profitability and minimizing environmental impacts will come from better management practices.

Lack of experience in managing pellet feeds could have significantly impacted the effectiveness and the results of using pellet feeds in the trials. In general, management practices (stocking, feed management as well as cage design) in marine cage fish farming are far from standardized - a factor that likely contributed to the poor results.

The trials were conducted in the different countries, and for various reasons, they cannot be strictly comparable. These reasons include species, feed types used and environmental differences between countries and sites. In addition, farm management practices varied between the individual farmers. Most of these differences were unquantifiable.

Species-specific diets for marine fish species are lacking for the majority of species cultured. The pellet feeds used in the farm trials were non-species specific, except the feed used for the barramundi trials, and of varying quality. Feed analyses showed the pellets used were generally acceptable for fish culture.

The common theme is that in terms of growth, there is no clear advantage in using either type of feed. The differences in performance were the result of feed management practices or possibly poor quality trash fish as was the case in China and possibly Viet Nam. Even within countries, management practices were highly variable between the farms. A controlled experiment using standard methods would have yielded a consistent difference between feed types. However, the resources of the project precluded any reasonable attempt at standardizing all variables and parameters across

the four countries for a controlled experiment. In any case, such a study would have yielded little practical results for application under actual farm situations and industry standards.

4.2 Practices and perceptions toward feed type and access to credit

Marine cage farmers' practices and perceptions, across the countries, had some similarities. However, there were a number of marked differences in their perceptions towards the two feed types and access to and the usefulness of credit.

Most farmers cultured more than one species. Farms varied greatly in terms of the numbers of cages per farm. Species cultured were groupers, red snapper, snubnose pompano, barramundi, cobia, golden trevally and lobsters. The number of cages in each farm varied, between 2 to 590, with averages of 96 in China, 53 in Indonesia, 25 in Thailand and 28 in Viet Nam.

Satiation feeding is practiced by most Chinese farmers and more than half of Vietnamese farmers. Farmers in Indonesia and Thailand tend to follow more controlled ration feeding.

Almost all farms in China and Indonesia and more than half of Vietnamese farms were using pellet feeds, while it was not common for farms in Thailand to use pellets.

Farmers experience difficulties in sourcing low-value fish and have to be content with variations in fish quality, especially during the monsoon and closed fishing seasons.

Farmers in Indonesia, Viet Nam and Thailand strongly believed that feeding low-value fish results in better fish growth and possibly better fish quality, while only about a third of the Chinese farmers surveyed held this belief. Most farmers in China and Viet Nam believed feeding pellet feeds is profitable, while majority of farmers in Indonesia and Thailand did not think so.

Despite their beliefs and concerns, the majority of farmers were willing to use pellet feeds; but they preferred that the pellet feed be species-specific and suited for the growth stage, of the stock. Pellet feeds are readily available in China and Indonesia, and moderately easy to get in Viet Nam, while in Thailand, they are remain unattainable for most cage farmers.

In general, the farmers understand the benefits from and disadvantages of using low-value fish and pellets. However, they lack the science based guidelines on management practices. Their farming practices and techniques are largely based on their experiences and perceptions.

Microcredit sources are mainly the banks. Farmers complained of high interest rates, difficult and lengthy procedures in obtaining credit, and the small amount of credit they were eligible for. Loans were taken out to build farm structures and purchase feed or seed.

4.3 Environmental impacts study

The environmental assessment results showed that that there was no significant measurable difference in impact in terms of dissolved nutrients (N, P, NH₃), dissolved oxygen and biotic and chemical impacts on sediments. This may have been due to the low stocking densities that were used in the farm trials - higher stocking density and input levels would likely to have shown different results. Poor feed management could produce environmental impacts and the study noted that some farmers tended to overfeed. The study found that:

- There were no significant differences, regardless of species cultured, in the environmental impacts associated with feeding either trash fish/low-value fish² or

² The assessments of impact on water quality and sediment were carried out in sites where the farmers were feeding with trash fish and pellet feed so that it was not possible to isolate the effects of either feed source.

commercial pellets. There were however increases in the bacterial loading in the trash fish that was stored on ice before feeding, as well as an increase in the levels of bacteria released to the environment when feeding 2- and 3-day old trash fish/low-value fish. Higher levels of nutrient leaching into the water column were observed from the use of pellet feeds in contrast to the use of trash fish/low-value fish.

- The energy required to produce a kilogramme of fish using trash fish/low-value fish was significantly lower than that required when using pellet feeds, and that the fish-in fish-out (FIFO) ratio for the production of a unit weight of marine fish was approximately three times lower with the use of pellet feeds than with trash fish/low-value fish.
- The lack of significant measurable differences in the impacts of feed type on water and sediment quality could be attributed to the low stocking densities used in the farm trials. Higher stocking densities and input levels would likely have produced different results. This affirms the significance of control measures such as zoning to limit farm numbers, and fish and feed inputs to ensure that effluent loads remain within the assimilative capacity of the environment.

The study notes that reducing the energy cost and the amount of fish needed to produce a unit weight of marine fish are issues that can also be addressed at the farm level. This can be achieved by improving general farm management, in particular feed and feed management practices.

4.4 Livelihood analysis and perceptions

The baseline survey of the livelihood status, prospects and strategies of fishers and traders of low-value fish showed basic differences between fisher households across the countries. In China, the suppliers use large vessels, with fishing being the sole source of income of almost all the fisher households. This commercial scale activity generated a considerably higher income for the Chinese fishers, as would be expected from their having larger fishing boats, than those in the other countries. On the other hand, fisher households in Indonesia, Thailand and Viet Nam engaged in diverse activities to supplement household incomes. In some instances these other activities earned the households more income than fishing.

The livelihood patterns of fisher households varied between the countries, so did their access to advice and assistance that could improve their livelihoods. Such sources of advice and assistance were widely available and accessed in Thailand, and were least available in China. The fisher households overwhelmingly ranked the education of their children and accumulating enough savings as the most important strategies for ensuring a comfortable future.

The most vulnerable to a shift from fish to pellet feeds appear to be the fishers in China; their livelihood options are limited unlike those in the other countries who have diversified sources of income. The closed fishing season in China renders them practically without employment throughout the duration of the closed season, and compared with the fishers from Indonesia, Thailand and Viet Nam, they have the least number of alternative livelihood options - unlike their counterparts in the other countries, their livelihood assets do not include crop lands and livestock. As they operate large boats, they have crew members that would need to find a new employment. In addition, it is more expensive to decommission a large fishing boat than the small artisanal boats such as those more commonly used by fishers in the other three countries. On the other hand, Chinese trawlers receive fuel subsidies that enable them to continue fishing, and the government has recently established a pension plan for fishers. Generally, the fishing households in all the four countries have reasonable levels of household assets to cope initially with a direct impact to their main livelihoods, which is fishing and supplying low-value fish.

5. BROADER REGIONAL CONCERNS ADDRESSED BY THE PROJECT

Some of the salient findings of the project are placed in a broader perspective by matching them with the conclusions of a regional workshop on low-value fish in the Asia-Pacific Region held in 2005 (AFPIC/FAO, 2005). The first set of issues identified by that workshop relate to the factors that make farmers continue to use trash fish. The second set relates to three factors that would move aquaculture away from the direct use of low-value fish, namely, profitability, efficiency of operation and the legality of operation. This exercise indicates whether the project has addressed the concerns of the earlier regional workshop.

The result shows that almost all of the issues were addressed by the project. Four issues were outside the project scope, which relate to non-fish substitutes for fish as feed, legislation on fishing that targets low-value fish, consumer pressure that is based on responsible farming practices, and traceability of feed ingredients. Nevertheless, these are in some ways and indirectly addressed by the project. The project for instance recommends BMPs, zoning, farmers' association, and integrated coastal zone management (ICZM) to ensure the development of a responsible and sustainable marine cage culture industry.

The exercise also showed that some of the issues raised by the 2005 workshop were not crucial to the transition to pellet feed such as **scaling up of operations** (this can be achieved by small-scale farmers being organized to achieve economy of scale); **profitability** (it is the efficient management including feeding practices to reduce waste and cost and a better market information and marketing that achieve better returns regardless of feed type); **the price of low-value fish** (it is not so much its being cheaper as the convenience of obtaining it and the smaller cash outlay needed to purchase a daily ration as well as the lack of credit facility that would enable farmers to buy pellet feeds), and taste (even in China there is an increasing number of farmers using pellet feeds and only about a third of the Chinese farmers surveyed held the belief that pellet feeding results in lower quality flesh or poorer taste).

Table 2 shows how the relevant project results match the conclusions of the 2005 regional workshop.

TABLE 2
Project results and their relevance to the conclusions of a 2005 regional workshop on low-value fish

| Drivers of the use of low-value fish in aquaculture | Project findings that address the 2005 workshop conclusions |
|--|--|
| 1. Practical considerations, habitual and traditional | <p><u>Some concurrence from the project.</u></p> <p>Using pellet feeds in the aquaculture of marine fish in cages was new to some of the trial farmers, particularly in Thailand and Viet Nam. Inexperience in managing pellet feeds could have lowered the efficacy of using the pellet feeds. Management practices (stocking, feeding management as well as cage design) in marine cage fish farming is far from standardized.</p> <p>Farmers' perceptions of the advantages of using low-value fish over pellet feeds in terms of fish growth, health (but not flesh quality), have been weakened or changed by the results of the trials. There were also clear indications that some of the traditional perceptions particularly in relation to weaning of the wild caught seed to pellets or changing from one feed type to the other were not true.</p> |
| 2. Convenient supply of fish particularly during certain seasons | <p><u>Most of the time, trash fish/low-value fish is readily available and pellet feeds are not.</u></p> <p>Generally, trash fish/low-value fish supply is seasonal. China has a 2.5 months closed season, and during this period, the farmers use formulated feeds; Indonesian and Vietnamese farmers also use pellet feeds when the low-value fish is scarce; Thai grouper farmers in the trials always use low-value fish, and if they have no catch, they go to the market to buy trash fish or trimmings such as head and bones and fish offal.</p> |
| 3. Low-value fish is still relatively cheap for aquaculture | <p>Prices for trash fish/low-value are increasing as are the ingredients for pellet feeds</p> <p>The price of trash fish is increasing, however, farmers purchase it daily which means they do not need to fund a large cash outlay at any one time. On the other hand pellet feeds are not readily available - especially in remote areas. In addition, prevailing client relationships between fish traders and farmers allows the farmers to buy low-value fish at preferential pre-agreed prices.</p> <p>With an increase in the price of low-value fish, pellets particularly those with low levels of fishmeal are likely to become more cost competitive.</p> |

TABLE 2 (CONTINUED)

| Drivers of the use of low-value fish in aquaculture | Project findings that address the 2005 workshop conclusions |
|--|---|
| 4. Farmers also fish for low-value fish (feed cost is offset as an opportunity cost of the farmers' time in fishing) | <p><u>Project finding concurs with this, but the convenience and time savings from using pellet feeds might offset this factor.</u></p> <p>Cage farmers in Thailand and Indonesia fish for food fish and use the low-value fish in the catch as feed. Fish farmers in China are supplied by large trawlers with a large proportion of low-value fish in their catch; farmers in Viet Nam buy from small fishers who fish for food fish and sell the by-catch to the cage farmers.</p> <p>However, farmers have realized the convenience, easier storage and longer storage life associated with using pellet feeds. And among the women, the time saved by using pellet feeds can be spent for other household chores and additional activities that generate income or produce food.</p> |
| Factors that will drive aquaculture away from the use of low-value fish | Project findings that relate to the 2005 workshop conclusions |
| a. Profitability | <p><u>Not clear from the results; there are many factors other than feed type.</u></p> <p>There were no statistically significant differences between the technical and economic performance of the two feed types fed to any of the culture species. Overall and with the exception of China, the trials indicated that the performance of the fish on low-value fish was slightly better, or in some instances hardly discernible.</p> <p>In the instances where one feed type outperformed the other, these were the result of farm feed management practices or possibly the poor quality of the low-value fish that was used. This was the case in China and possibly Viet Nam. Management practices of farmers were highly variable even within a country.</p> <p>The comparative results:</p> <p>Feed cost of producing one kilogramme of fish are: orange spotted grouper in China, US\$3.08 for pellets and US\$5.33 for trash fish/low-value fish; brown-marbled grouper in Indonesia, US\$3.32 for pellet and US\$3.40 for low-value fish; brown-marbled grouper in Thailand, US\$4.12 for pellet and US\$4.38 for trash fish/low-value fish; red snapper in China, US\$1.57 for pellet and US\$2.14 from trash fish/low-value fish, and red snapper in Viet Nam US\$4.18 for pellet and US\$2.43 from trash fish/low-value fish. The Vietnamese diet was a high quality feed imported from Norway for which nutritive values exceeded the requirement of the species.</p> |
| 1. Increase in the price of trash fish/low-value fish | <p><u>Study finding in Viet Nam concurs with statement.</u></p> <p>A survey of marine trash fish/low-value fish and fishmeal use in Viet Nam indicated that there has been a dramatic rise in the use of low-value fish in aquaculture (in addition to other uses such as small-scale pig farming) with a probable doubling of its price. This indicates that aquaculture based on traditional use of low-value fish as a direct feed is unlikely to be able to expand further. The bulk of fishmeal used in aquaculture feeds in Viet Nam is imported as locally produced fishmeal is generally of poor quality with a low protein content, and the price of imported fishmeal is increasing. Therefore, future price increases and the development of alternative effective feed ingredients for pelletized feeds will drive changes in cost effectiveness of the different feed types.</p> |
| 2. Increased competition for alternative uses (such as for direct human consumption) | <p><u>No evidence was derived from the project; it was not within the scope of the project.</u></p> <p>In Indonesia, there is competition for low-value fish from fishmeal manufacturers who offer a higher price than those of the farmers – the converse is true in the other three countries. But the Indonesian fishers and traders prefer to sell to farmers because they are paid cash on delivery while the processors delay their payments.</p> <p>Fishers in China used to be able to sell low-value fish for salting, and the fish was subsequently sold as food fish to inland communities. However, increases in incomes and the rise of a middle class have changed food preferences, and salted fish is no longer preferred nor profitable.</p> |
| 3. Scaling up of aquaculture units: would require pellet feeds | <p><u>Findings provide some evidence to support this position. There is also evidence that this is not a strict requisite; small farmers being organized can achieve similar scale-up effects. The as yet unreliable supply and poor quality of seed of most of the cultured high value species will hold back expansion to large scale operations. Industrial scale operations will hasten the wide adoption of pellets, however earlier reviews suggest that expansion will be very slow in Asia.</u></p> <p>The average number of cage units of the trial farmers in China was 101. In Indonesia, the farmers owned from 45 to 120 cages, and in Viet Nam from 4 to 70. Large or small-scale, the cage farmers continue to use low-value fish for reasons such as its general availability, and the physical and financial constraints to procuring pellet feeds.</p> <p>On the other hand the project found that the convenience of using pellet feeds is being noted by farmers and their wives who do most of the feed preparation and feeding. The time saved in preparing trash fish can be spent for other household, farm and income generating activities.</p> <p>For small scale operators scaling up could be achieved by becoming organized into farmer groups, and gaining economies of scale and better leverage in terms of buying feed in bulk at a discount, receiving more commercial attention and technical advice from feed manufacturers and distributors. The project encouraged the formation and effective functioning of farmer groups. It also brought in the participation of feed manufacturing companies.</p> |

TABLE 2 (CONTINUED)

| Drivers of the use of low-value fish in aquaculture | Project findings that address the 2005 workshop conclusions |
|---|---|
| 4. Disease outbreaks | <p><u>Not supported by evidence, but the disease risk is higher when using low-value fish.</u></p> <p>Disease outbreaks were not attributed to either type of feed, but rather to the water quality at the culture sites, their location in relation to land-based sources of discharge, the density of cages in the area, and other risk factors. However, there is a greater risk of parasite and disease introduction when using low-value fish. The environmental component of the project found increased bacterial leaching from low-value fish, especially in terms of the length of time that it had been stored on ice. An analysis of the bacterial loading of trash fish and pellet samples kept on ice for an increasing number of days showed a significantly higher bacterial loading in trash fish than pellets, and that this loading increased over time.</p> |
| b. Efficiency of operation | |
| 1. General unavailability, seasonality or uncertainty in the supply of low-value fish | <p><u>Not a critical factor with the low stocking densities and low volumes of production.</u></p> <p>The survey of low-value fish suppliers indicates seasonality of catch, and that during the scarce season, farmers do resort to feeding with formulated commercial feeds.</p> |
| 2. Pellet feed readily available at reasonable prices | <p>The project finding supports this position.</p> <p>The participation of feed manufacturers in project brought their attention to the constraints faced by the farmers, one of which is lack of credit or the insufficient amount granted by lending institution. A microcredit facility would help, and the ability to buy in bulk at a discount- by being organized into farmer associations - would facilitate adoption of pellets.</p> |
| 3. Information, knowledge, education and demonstration of the value of pellet feed | <p><u>High priority.</u></p> <p>The project generated a significant body of information that will be useful to the marine cage finfish farming community, the feed manufacturing sector, and to the aquaculture sector in general. The private sector has already taken the initiative to fund the production of some extension materials prepared by NACA. Others will consider formulating species-specific feeds.</p> <p>Some of the results could be published in peer reviewed journals, some in other publications such as Aquaculture Asia, FAO Aquaculture Newsletter and other media.</p> <p>Demonstration projects and farmer-to-farmer learning activities were suggested.</p> |
| 4. Increasing knowledge about the inefficiency of poor quality of low-value fish (farm economics, water quality, and wider environmental pollution) | <p><u>A set of BMPs and technical guidelines on specific operations in marine cage culture using many of the project findings was recommended by the stakeholders' workshop.</u></p> <p>Regardless of feed type, it is the farm practices and natural conditions of the sites that caused the variations in performance.</p> <p>In general, the farm trials demonstrated the technical feasibility of using pellet feeds to replace the direct use of low-value fish in marine finfish culture in cage. It was concluded that pellet feeds offers a viable alternative to using low-value fish for marine finfish cage culture. However, the farmers are aware that most of the commercial feeds are not species-specific (with the exception of the barramundi feed that was used in Thailand), and that they are not specific to the life-stage of the fish i.e. starter, grower, finisher diets. Thus, the diets may have produced poorer performance than could be reasonably expected. The project raised awareness of this issue with the feed manufacturers.</p> |
| 5. Overcome taste issues from the use of pellet feeds | <p><u>The project confirmed this prevailing farmers' perception.</u></p> <p>It was suggested that a way to accommodate this perception was to purge the fish before harvest, and to finish them on low-value fish.</p> <p>The farmer trials have generally changed the farmers' perception that pellet feeds leads to poor growth and lower fish flesh quality.</p> <p>More farmers are moving away from low-value fish to pellet feeds in China.</p> |
| 6. Increased availability of cost-efficient substitutes (plant proteins, terrestrial animal meals, fish processing by-products) | <p><u>Not within the scope of the project.</u></p> <p>The energy used per kilogramme of fish produced ranged from 3.96 MJ/kg fish in Thailand where a small dedicated boat was used for catching low-value fish to, 44.35 MJ/kg fish in Thailand and Viet Nam where pellet feeds were used, and 81.48 MJ/kg fish for commercial trawlers catching low-value fish as a bycatch in Indonesia. These calculations demonstrate that much higher energy is embodied in the amount of pellet feeds that are required to produce one kilogramme of farmed fish than in low-value fish. While this is cause for concern, the issue should be framed not in terms of pellet feed vs. low-value fish, but the use of fishmeal vs. other ingredients in the pellet feed formulations.</p> <p>Another measure, FIFO or fish-in fish-out, showed that nearly three times more of fish is required to produce one kilogramme of farmed fish by using low-value fish than by using pellet feeds. This is also an indicator of the environmental impact of the use of low-value fish and should be framed within the better farm management practice issue.</p> |

TABLE 2 (CONTINUED)

| Drivers of the use of low-value fish in aquaculture | Project findings that address the 2005 workshop conclusions |
|--|---|
| c. Legality and compliance of operation | |
| 1. Legislation against polluting practices | <p><u>Supportive of this but not solely in terms of legislation.</u></p> <p>The project saw the need for better site selection, zoning and, more broadly, integrated coastal zone management, to complement better management practices which should be reinforced by farmers organizing into clusters, clubs or associations.</p> <p>There were no apparent differences in impacts measured in terms of dissolved nutrients (N and P, NH₃), and dissolved oxygen at the sites. This was attributed to the low stocking densities used in the farm trials.</p> |
| 2. Legislation or policy to prevent targeted catch | <p><u>Not within the scope of project.</u></p> <p>Commercial trawlers in China target food fish but an increasing proportion of their catch is now low-value fish, particularly the demersal ribbon fish, for sale specifically as a raw material for fishmeal. The higher value pelagics in their traditional fishing grounds have become very scarce. The fishing pressure is intense with 10 000 boats operating in pair trawling powered by 450–600 hp engines. They receive a fuel subsidy. An annual 2.5 month closed season is in force to allow the resource to recover. The efficacy of this management measure needs to be established and is a research issue. The fishers in the three other countries target food fish and sell the bycatch and low-value fish to farmers or the fishmeal processors.</p> <p>A suggestion from the final regional stakeholders' workshop was to study the origins, catch volumes, and species composition of low-value fish catches.</p> |
| 3. Pressure from consumers for sustainably produced aquatic products | <p><u>Not within the scope of the project.</u></p> <p>As yet, this is not a factor in the regional and local markets in Southeast Asia and Southern China. Consumer priorities focus on quality, safety from heavy metals and toxins such as ciguatera, whether the fish is alive or dead, whether it was caught by cyanide, and other attributes. The consumer's purchasing decision may or may not include how responsibly the fish was farmed or, as the issue below raises, what substances were in the feed that were fed to the fish. There is however a Live Reef Food Fish (LRFF) Standard (The Nature Conservancy, 2004) that has been developed and issued for voluntary adoption by institutions and individuals engaged in the trade in live reef food fish. It has provisions on the management and operational requirements for aquaculture.</p> |
| 4. Requirement for feed ingredient traceability to allow for the export of the product | <p><u>Not within the scope of project.</u></p> <p>See preceding issue.</p> |

6. OPPORTUNITIES IDENTIFIED

The foregoing discussion has identified a number of opportunities that can be addressed with further activities. A number of these are cross cutting issues (discussed in Section VIII). These include:

6.1 Policy and regulations

- 1) Reducing fishing capacity and providing assistance to develop alternative livelihoods to fishers.
- 2) Incentives to boat owners for investments in technology to improve on-board fish preservation and quality
- 3) Re-examination of fuel subsidies to fishers vs. market based incentives
- 4) Zoning guidelines
- 5) Policy guidelines for offshore mariculture.

6.2 Research and development

- 1) Determination of the nutritional requirements of cultured species in collaboration with feed manufacturers.
- 2) Development of food product forms from low-value fish which can be informed by a survey of food preparations from processors and small vendors and consumer preferences.
- 3) Intensification of research and training on breeding to produce hatchery bred seed, nutrition and feeding of fry and fingerlings, which can be facilitated by the regional network programme, e.g. Asia-Pacific Marine Finfish Aquaculture Network of NACA.

- 4) Development of a seed production and distribution system to assure the reliable supply of quality juveniles for on-growing. Lessons from the Indonesian satellite system of producing and distributing fertilized grouper eggs, fry and juveniles can be adapted for use in other areas.
- 5) Identifying the disease risk factors associated with the use of low-value fish.

6.3 Extension, information and training

- 1) Better management practices
- 2) Pilot demonstration projects
- 3) Farmers and extension workers training
- 4) Farmer-to-farmer extension
- 5) Farmers associations

6.4 Market access

- 1) Organized marketing
- 2) Market intelligence and better access to market information
- 3) Standards and certification

6.5 Public-private partnership

- 1) Government – Academic Institutions – Professional associations – Feed Manufacturers – Seed Producers – Supply distributors – Fish farmers Associations – Exporters
 - for policy, industry regulation, and trading
 - research and technology development in feed and seed
 - supply distribution and marketing

6.6 Regional cooperation

- 1) Policy guides for offshore mariculture
- 2) R&D in fishery resource management
- 3) Extension – information exchange, development and capacity building for BMPs
- 4) Market access – trade information, capacity building, standards and certification
- 5) PPP – models of public-private partnership

IV. Farmers' participatory trials

1. RATIONALE

This component was the core of the project. Under farm rather than experimental conditions, and with the farmers being advised by technical experts in the farm management including feeding practices, it sought to assess three performance indicators: growth, feed utilization and feed cost of production. Its practical purpose was to establish the technical and economic rationale for persuading the farmers to switch to commercial pellet feeds. A corollary was to improve the feed management practices, regardless of the feed type they use.

2. SUMMARY OF FINDINGS³

The salient findings are as follows:

- The farm trials generally demonstrated the technical feasibility of using pellet feeds to replace the direct use of low-value fish in marine finfish cage culture. It was thus established that pellet feeds offer a viable alternative to low-value fish as a feed source for marine finfish cage culture in the long run.
- The farm trials showed that the use of pellet feeds has achieved similar performance to the direct use of low-value fish in terms of growth, survival, food conversion, production and economic benefits although the results varied between countries. The variation in the results was due to different farming and management practices (e.g. farm type, cage size, types of cage, and species).
- Generally, feed type did not make much of a difference in growth or cost performance, except with low-value fish that was of poor quality as was the case in China and possibly Viet Nam. This was reflected in the lower growth of the orange-spotted grouper in China and both the snubnose pompano and red snapper in Viet Nam that were fed with poor quality low-value fish. In all cases, no clear indication (i.e. no statistically significant difference) was observed between performance indices when using either the low-value fish or the pellet feeds.
- Using pellet feeds in the aquaculture of marine fish in cages was new to some of the trial farmers, particularly in Thailand and Viet Nam. Inexperience in managing pellet feeds could have affected the effectiveness and results of using these feeds in the trials. In general, management practices (i.e., stocking, feeding, cage design) in marine cage fish farming are far from standardized, which leads to poor results.
- Management practices and growth and feed utilization vary widely between farmers within each country and between the countries. In this respect, the greatest potential for improvements in growth, feed utilization and ultimately farm profitability and environmental sustainability are likely to come from better management practices.
- Species-specific diets for marine fish species are lacking for the majority of the species cultured and the availability of many marine finfish diets could be improved, especially in Thailand.
- The trials were conducted in the different countries and cannot be strictly comparable for various reasons. The reasons include species, feed types used and environmental differences between countries and sites, as well as aspects of farm management. Most of these differences were unquantifiable.

³ The details of the methodology and results are found in the full report, which appears as Annex 1.

- In general, pellet feeds used in the farm trials were non-species specific and of varying quality. The feed analyses data showed that pellet feeds were generally acceptable for fish culture. For instance the analysed diets contained up to about 9.5 percent moisture (spoilage from microbial activity is likely when feed contains more than 12 percent moisture) and levels of other parameters appear acceptable. However, the ash content of some diets used in the trial in China appeared to approach levels that are detrimental to growth - high ash fishmeal diets can result in zinc deficiencies in cultured fish.

The findings need to be qualified with these considerations. The culture species varied as did farm size and farming practices. The trials in each country were designed to replicate and maintain similar conditions between trial cages and fish with the exception being the type of feed used. However, although the methodology was the same, similar conditions were not maintained across the countries. Each country effectively operated as a separate trial with different commercial feed types used, different environmental parameters at sites, different management paradigms, and species cultured. Most of these differences could not be factored into the analysis. Thus conclusions from any direct comparisons were made in the context of this limitation.

3. METHODOLOGY

While there was a common procedure for all trials, in each country there were variations in trial design, species cultured, and the management systems applied. All the trials were designed to compare growth, feed utilization and economic performance. Water quality differences and disease occurrences were monitored. Performance measures were (i) specific growth rate (SGR; percent body weight gain/day), (ii) food conversion ratio (FCR), (iii) condition factor (CF) and (iv) feed cost of production (feed cost/kg fish produced). The formulae are presented in Annex 1.

A number of different species, all being commercially farmed, were used in the growth and feed utilization trials. The species cultured in the trials at the different locations were red snapper (*Lutjanus erythropterus*) and orange-spotted/green grouper (*Epinephelus coioides*) in Guangdong, China, brown-marbled/tiger grouper (*Epinephelus fuscoguttatus*) in Bandar Lampung, Indonesia, barramundi or Asian seabass (*Lates calcalifer*) and brown-marbled grouper in the west coast provinces of Krabi, Phuket and Phang Nga, Thailand, and snubnose pompano (*Trachinotus blochii*) and red snapper in Nha Trang, Viet Nam.

Selected pellet feeds used in each country study were analysed for proximate and amino acid composition in triplicate by standard methods.

4. FINDINGS

This section presents the highlights of the country trials. The details are in Annex 1.

4.1 China

Five farmers participated in the trials. They were commercially farming red snapper (*Lutjanus erythropterus*), cobia (*Rachycentron canadum* Linnaeus, 1766), snubnose pompano (*Trachinotus blochii* Lacepède, 1801), and grouper (*Epinephelus* spp.). Each farmer owned between 36 and 173 cages. In the trials, the farmers agreed to culture either red snapper or orange-spotted grouper. In the trial, three farmers cultured red snapper and two cultured orange-spotted grouper. The trial farmers received training and orientation on the significance of the trial, and the operational procedures.

4.1.1 Results

Overall growth and feed utilization. Overall orange-spotted grouper fed with pellets had a significantly higher mean weight than those fed trash fish, no other growth and feed utilization parameters were significantly different between the fish fed pellets or

trash fish. The FCRs and survival of red snapper fed pellets were very good while that of orange-spotted grouper were acceptable.

Economic performance. The per unit cost of feed used in the China trial was CNY8/kg of pellets for both species, and CNY2.87/kg for trash fish. Based on the mean food conversion ratios from the trials, the cost of pellet feed to produce one kilogramme of orange-spotted grouper using pellet feeds was CNY20 (US\$3.08) and that on trash fish was 35 CNY (US\$5.33). Similarly, the cost to produce 1kg of red snapper on pellets was CNY19.4 (US\$1.6). On trash fish, it was CNY14.3 (US\$2.1).

Water quality. No statistically significant differences in water quality parameters were found between the cage sites using pellet feeds or low-value fish. Water temperatures above 30°C were recorded in August, September and October after which they decreased. During most of the trial period, the range of pH values varied between 8.3 and 8.9 and were favourable for marine cage farming. However, after late September and early October, pH values dropped to 7.5 and below at some farms, such low pH values were unfavourable for fish growth.

Disease. The trial farms became infected by disease during the trial with *Benedeniasis* infection occurring in the initial weeks of the trial (April and May), bacterial diseases in mid trial (June to August), and *Cryptocaroniasis* towards the end of the trial (October). Both trial sites experienced disease outbreaks.

Parasites especially *Benedeniasis* affected the early stage (April to May) of the trial. Fresh water bath treatments with potassium permanganate effectively controlled the parasite. The middle stage of the trial (June to August) featured high water temperatures and bacterial diseases caused a significant impact. Both trial species experienced high mortality. For example, at Farm 1, the orange-spotted grouper monitored in July, and at Farm 2, the orange-spotted grouper monitored in August suffered over 50 percent mortality rates. *Cryptocaryon irritans* was the main disease agent during the final stages of the trial.

Disease was a major factor that affected the outcome of the trial and is common throughout the industry in China.

Pellet feed quality. As the trial used commercial diets and the dietary ingredient composition, digestibility and fatty acid composition were not known it was difficult to conclude the appropriateness of the commercial diets for the species cultured. However, based on the analyzed proximate and amino acid composition the diets, they appear to be acceptable. The results of the amino acid analysis should be treated with caution as the sample was refrigerated for many months prior to analysis. The length of storage increases the possibility that amino acids were utilized by microorganisms, had oxidized, or changed in form.

4.2 Indonesia

Six farmers participated in the trials, all of them raising brown-marbled grouper, humpback grouper and other species. Most farmers used the same cage size but the number of cages owned by the farms differed considerably. The farmers were located in different coastal areas, all within 35 km of Bandar Lampung, Sumatra. The trials were based on the brown-marbled grouper (*E. fuscoguttatus*). Some farmers practice feeding different parts of the fish to different species, such as feeding the tail or fillet parts to the higher valued humpback grouper or leopard coral grouper while the remaining portions (head or head and backbone with most the meat stripped) are fed to the lower value species such as brown-marbled grouper, red snapper or cobia.

4.2.1 Results

Overall growth and feed utilization. Across all the trial farms, the brown-marbled grouper fed with low-value fish had a higher mean weight, mean length, condition factor, survival, specific growth rate, consumption rate, and FCR, than those fed the pellet feeds. However, only the amount of feed fed and FCRs were significantly different ($P < 0.05$).

Economic performance. Four of the six farms reported a lower feed cost of production when using low-value fish, but this finding was not statistically significant. One farm reported a statistically significant difference in the feed cost of production when using the low-value fish.

The feed cost per kilogramme was US\$1.35 (IDR⁴ 12 000) for pellet feeds and US\$0.56 (IDR5 000) for low-value fish. As the growth rates between fish fed the different feed types were not significantly different, the economic efficiency between the two feed types can be evaluated on feed cost of production basis. But the results show that feeding with pellet feeds or low-value fish made very little difference to the economic performance of brown-marbled grouper culture in Indonesia.

Water quality. The trial farms were located in different embayments, where there were different local water circulation and land use patterns (such as shrimp farm ponds and other cage farming activities in the area). These had impacts on water quality. However, in general, the water quality parameters measured at the trial farms were within the acceptable limits for grouper culture. Low dissolved oxygen levels (3.81 mg/l) were recorded on one occasion. Furthermore, phytoplankton blooms occurred in the first two months - these including harmful algae species such as *Noctiluca* sp, *Thalassiosira* sp, *Pyrodinium* sp, and *Dinophysis* sp. In addition to toxic substances in some of the algae species, the algae was also seen to coat the gills of the fish.

Disease. Disease events occurred three times. At the beginning of the project (April–June 2009), the middle (October–November 2009) and towards the end of the project (January–February 2010). At the beginning of the project, a disease outbreak occurred resulting in a very high fish mortality rate. During the middle of the project, the disease status was stable, but there were still fish mortalities that were attributed to changes in water quality. Towards the end of the project, the disease status was more stable with much less or no mortality occurring.

During the first month of fish health monitoring programme, the grouper were affected by parasites, bacteria and viruses at all the sites. The bacteria identified in the liver, spleen and kidneys were: *Vibrio fluvialis*, *Vibrio alginoliticus*, *Vibrio vulnificus*. A *Coccus* shaped bacteria in the gills was identified as a *Flavobacterium*. The analyses also found *Pseudorhabdosynochus* sp. *Trematoda* sp. and *Trichodina* sp. parasites in the gills and skin of the fish.

Fish raised in Tanjung Putus (two farms) and Tegal Arum (one farm) showed mild to moderate infections of viral nervous necrosis (VNN). Similarly, enlarged cell walls indicated the presence of a native viral infection. The three other farms showed no evidence of VNN infections. In the second month of monitoring, most of the fish trials, and across several locations, showed higher infection rates of VNN and an iridovirus. This resulted in continued mortality. The viruses were found in almost all the target organs such as spleen, kidney and thymus.

The survival rate was lower than the industry standards due to harmful algal bloom and disease problems and high mortality rates that were prevalent at the start of the trial. The overall economic performance was thus lower than expected.

⁴ 1 US\$ = 9 100 Indonesian rupiah.



Marine cages in Lampung Bay, Bandar Lampung, Indonesia. In this bay, the farmers culture a number of fish species including grouper, red snapper and cobia. Among grouper species, brown-marbled and humpback groupers are mostly cultured. The number of cages in each farm varies between 45 and 120 with most of the farmers using a similar size (27 m³) of cage.

Courtesy of FAO/Mohammad Hasan

Pellet feed quality. The dietary requirements of the brown-marbled grouper (*E. fuscoguttatus*) is reported to be 47 percent crude protein and 9 percent crude lipid for juveniles (from ≈5 to ≈40 grams individual body weight) (Giri, Suwirya and Marzuqi, 2004). For larger brown-marbled grouper (80 to 300 g), 51 percent crude protein is reported as optimal. Of the commercial pellets used in the trial in Indonesia, the 3 mm, 5 mm and 10 mm pellets all appear to have sufficient crude protein levels. The 7 mm pellets appear to contain slightly less crude protein than the optimal level for brown-marbled grouper. All the commercial pellets appear to contain above the optimal levels of lipid, particularly the 3 mm, 5 mm and 7 mm diets. The elevated lipid levels may result in increased fatty deposits in the body of the fish.

4.3 Thailand

Groups of four farmers were selected in the southwest provinces of Phang Nga, Phuket and Krabi. The farmers had over three years of experience in culturing at least one of the two trial species, and used low-value fish as the feed source. The trials were based on barramundi (*Lates calcarifer*) and the brown-marbled grouper (*E. fuscoguttatus*).

4.3.1 Results

Overall growth and feed utilization. The growth and feed utilization of barramundi considering all farms combined at a common period (130–134 days after stocking) showed no significant difference in individual fish weight, survival, growth rate or biomass increase per cage. Significant differences were observed in individual fish lengths; pellet-fed barramundi were shorter than low-value fish fed barramundi. Condition factor was also greater in the pellet-fed barramundi due to their shorter length but similar weight.

The growth and feed utilization of brown-marbled grouper considering all farms combined at a common period (251–254 days after stocking) showed significant difference only in the condition factor of fish, with pellet fed fish having a higher condition factor than those fed with low-value fish.

In terms of feeding rates (expressed as the percentage body weight of feed fed per day), it was observed that the feeding practices of farmers were highly variable, and there were large differences in the feeding rates that were applied to each feed type, and for each size class of fish.

Economic performance. The feed cost of production of brown-marbled grouper was not significantly different between those on pellets and those on low-value fish. However, in comparison with the pellet feed, the feed cost of production was significantly lower for barramundi fed on low-value fish.

Water quality. The water quality parameters monitored at the trial farms were all within the suitable range for the culture of barramundi and brown-marbled grouper. Temperature was not recorded as a parameter during the trials. However, on 22–23 December 2009, it decreased rapidly to 22°C at some farm sites, and caused mortalities. The cages that suffered from this mortality were excluded from the growth and feed utilization analysis.

No significant differences ($P>0.05$) were found between any of the water quality parameters at any of the barramundi or brown-marbled grouper farms. However, a significant difference ($P<0.05$) in salinity was observed between barramundi Farm 1 (31.3 ± 0.6 ‰) and the other the barramundi farms.

With the exception of the ammonia concentrations inside and outside the cages, significant differences ($P<0.05$) were found between brown-marbled grouper trial farms in terms of salinity, transparency and dissolved oxygen concentration (surface, bottom and outside cages). No trend between feed type and farm was observed ($P>0.05$) for any of the water quality parameters measured.



Grouper cages in Krabi estuary, Khlung Prasong district, Thailand. Among grouper species, brown-marbled grouper is mostly cultured in Thailand. Cage sizes in this area are generally small varying between 10 and 18 m².

Courtesy of FAO/Mohammad Hasan

Pellet feed quality. The feeds ranged between 7–9 percent moisture, ≈40–45 percent protein, ≈8–11 percent lipid and ≈11–13 percent ash. Some variability was noted between the amino acid compositions of the different feeds fed to the different size classes of fish. The sum of the amino acids measured on an “as feed basis” equates to 88 percent, 86 percent, 71 percent and 99 percent of the analysed crude protein for the 3–4 mm, 6 mm, 9 mm and 12 mm pellet feeds, respectively.

4.4 Viet Nam

Ten farmers participated in the trials culturing snubnose pompano (*Trachinotus blochii*). One farm also cultured red snapper (*Lutjanus erythropterus*). Across all the trials, one cage was allocated to each feed type at each farm,

4.4.1 Results

Overall growth and feed utilization. In contrast to feeding low-value fish, the Snubnose pompano fed pellets displayed significantly ($P < 0.05$) higher mean weight gains, and significantly lower FCR and total consumption per cage. Survival and SGR were higher when the fish were fed pellet feeds, however, these findings were not statistically significant ($P > 0.05$). The improved growth performance observed with pellet feeds maybe attributed to the high quality of the pellets, and poor quality of the low-value fish. Low-value fish in Viet Nam has been reported to be of poor quality due to inadequate on-board preservation. This is especially true in the offshore fisheries where vessels may be at sea for periods of up to 1 to 6 weeks. A similar situation exists in China where much of the low-value fish comes from the offshore fisheries.

Economic performance. Feed cost of production was higher for pellet feeds than low-value fish for both species, by about 1.4 times and 1.6 times for snubnose pompano and red snapper respectively. The FCRs of the snubnose pompano that were fed pellet feeds varied between 2.3 and 3.4. The same level of variation was also noted when low-value fish was used as the feed source with FCRs ranging between 10 and 17. This suggests that substantial feed losses were occurring in some of the farms, and that regardless of feeds type, improvements in farming practices could achieve substantial increases in profitability, and reductions in the environmental impacts associated with feed use.

Water quality. No statistically significant differences in water quality parameters were found at the trial cage sites. However, there were some differences in water quality (e.g. ammonia) between farms. These local differences were attributed to the differences in the hydrological conditions at the sites, for example, water depth and current profiles. The location of the trial farms in relation to other cage farms (some cages were located in close proximity to other farmers) would have reduced water circulation and impacted on local water quality. However, it was established that the water quality at the sites was suitable for the culture species.

Pellet feed quality. As it was originally intended to use grouper in the trial, the feed company designed and produced a feed for grouper. However, due to the difficulties in obtaining grouper juveniles, the culture species was changed to snubnose pompano and red snapper. As the feed had already been produced so that a change in the composition of the feed could not be done so that the trial proceeded with the pellet feeds that were designed for grouper.

The dietary requirement for snubnose pompano (*T. blochii*) could not be found in published literature. However, the dietary requirement for the closely related Florida pompano (*T. carolinus*) is reported to be about 36 percent protein and 20 percent lipid or a minimum of 45 percent crude protein and 8 percent lipid diet. With the

information on the dietary requirements for snubnose pompano based on what is known for a related species, it appears that the diet used in the trial provided a fairly good approximation of their dietary requirements.

In order to approximate the dietary requirements of the red snapper, the dietary requirements of a closely related species, the mangrove red snapper (*Lutjanus argentimaculatus*) was used. The mangrove red snapper has a dietary requirement of around 41–43 percent protein, and 9–12 percent lipid. In this respect, the dietary formulation used in the Viet Nam trial contained excess protein. To some extent, the excess protein in the diet may be limiting growth because the fish may be expending energy on the deamination of the excess protein. However, the fish in the trials grew well, with the fish fed the pellet feeds growing faster than those fed the low-value fish. The feed company representative also reported that the diet contained a high level of fishmeal, thus making it highly digestible and nutritious.

5. SYNTHESIS OF RESULTS IN FOUR COUNTRIES

The trials in each country were designed to replicate and maintain similar culture conditions between trial cages. Although a similar methodology was used, similar culture conditions could not be maintained across the countries. Therefore, each country effectively operated as a separate trial with different commercial feed types, environmental parameters, individual farmer management regimes, and culture species. Most of these differences were unquantifiable. It is in this context and with this limitation that conclusions derived from the study were made. The comparisons are made on the basis of the species cultured.

5.1 Groupers

Overall, there is wide variability in the performance parameters within and between the countries. However, the differences between growth rates and survival within each country were relatively similar.

The survival rates of the fish in the different countries, were primarily influenced by disease (by water quality related plankton blooms in the case of Indonesia), and were lowest in China, followed by Indonesia. Survival rates were highest in Thailand. This finding coincides with the density of farms at the culture sites with farms in China being of much higher density and those in Thailand of much lower density.

Considerable differences were also observed in feed utilization. The FCR associated with the use of pellets was about 2.5 in China and Indonesia, but more than 3 in Thailand. The FCR of low-value fish was 12–13 in China and Thailand, and six in Indonesia. Even if the FCRs were slightly under estimated, the differences are still large. The higher FCR associated with the use of pellet feeds in Thailand may be due to the marine cage farmers' inexperience in feeding pellet feeds. In contrast, in China and Indonesia pellet feeds are available, and many farmers have had previous experience with feeding pellets.

Although environmental conditions will have influenced fish growth, survival and feed utilization between the countries and across the different farms, many of these differences can be attributed to differences in feed management practices. Feeding practices such as frequency and ration rate can significantly influence fish performance. Feeding and feed management differences were noted to vary widely among both the trial farms, and across the countries.

5.2 Red snapper

Between the countries, there were variations in the stocking sizes and densities, culture periods, and the composition and the prices of the pellet and low-value fish feeds. These differences precluded the direct comparison of the results attained from each country. Aside from the final mean weight, few differences were observed between the

growth and feed utilization performance of the red snapper in Viet Nam. In China, much lower FCRs were obtained. This suggests that in Viet Nam, there is considerable room for improvement in feed management practices.

A comparison of the feed cost of production between using pellet and low-value fish feeds showed different trends in China and Viet Nam. The difference was primarily a result of the differences in the cost of pellets and low-value fish in each country. Had the cost of the feeds been the same between the countries, the trends in economic performance would have been similar.

5.3 Barramundi and snubnose pompano

As the barramundi and snubnose pompano were only cultured in one country, the results of the trials could not be compared between countries. However, in the context of the overall study, very little difference was seen in terms of growth rate and survival between feed types.

5.4 Pellet feeds

Generally, the pellet feeds that were used in the trial were of moderate to high quality. However, there was little information with which to base an assessment of their suitability as a feed for each of the culture species. The pellets were not specifically designed for the cultured species. Diets contained the high levels of crude protein and moderate levels of crude lipid that are generally required by carnivorous marine fish. Ash, fibre, calcium and phosphorous levels all appeared to be within a suitable range for warm water fish.

5.5 Common theme

In terms of optimizing growth, the trials showed no clear advantage in using either feed type. There were instances when one feed type outperformed the other, but this was a result of the farmers' feed management practices, or the poor quality of the low-value fish that was available - as was the case in China, and possibly Viet Nam. Even within countries, management practices were highly variable. Had a controlled experiment using standard methods been used, a consistent difference between the feed types may have been established. However, such findings would have had little relevance in terms of current farming practices nor would they have reflected the environmental benefits, under industry standards, of using a particular feed type.

To conclude, it is evident that a large amount of feed in the trials was not consumed by the target animals, and that feed wastage is more often as a result of poor feed management than feed composition.

V. Farmers' perceptions

1. RATIONALE

Anecdotal information abounds on the reasons for farmers' preference for low-value fish to commercial feeds. The project sought to collect this information and assess its prevalence. The aim of the farmer perception survey was to understand farmers' perceptions about the use and performance of low-value fish and pellets, the problems they experience, the feed source supplies, and the use of microcredit schemes to finance their cage culture operations. The practical application of this component of the study was to address the technical, economic and socio-cultural issues associated with their perceptions.

2. METHODOLOGY

A questionnaire was developed for all of the case study countries and translated into the local language. The responses were translated from the local language into English and analysed. In addition to the structured survey, farmers' perceptions on feed use, feed performance and microcredit were assessed and discussed during stakeholder workshops.

3. FINDINGS

3.1 China

A survey of 29 marine cage fish farmers was undertaken to assess their perceptions on fish feed quality, availability, usage and microcredit schemes relevant to marine cage farming. The survey was undertaken in July 2010 around the coastal area and islands in Zhanjiang bay and Leizhou bay, Guangdong province. The main species cultured by the surveyed farmers were red snapper (*Lutjanus erythropterus*), snubnose pompano (*Trachinotus blochii*), and the orange-spotted grouper (*Epinephelus coioides*). A small volume of other species was cultured. Each farm cultured multiple (at least two) species. The surveyed farmers had on average 96 cages; the range was 12 to 590 cages per farmer.

On low-value fish. The great majority of farmers thought that the use of pellet feeds offered many advantages over low-value fish, and equally realised that the sourcing of low-value fish was difficult and its quality variable. Obtaining good quality low-value fish for mariculture is a problem in China, where it is supplied by commercial trawlers which are primarily directed towards the fishmeal industry. Trawlers land their catch after 7 to 14 days at sea, as such the quality is often poor, and the fish poorly preserved. In addition, in comparison with the other trial countries that source their fish from semi-commercial or artisanal fisheries, the price of low-value fish in China is relatively high, it is not fit for chopping, and has to be minced which results in a significant loss in nutrients during both feed preparation and feeding.

Twenty-seven of the surveyed farmers (93 percent) had difficulty sourcing low-value fish. Twenty six (90 percent) respondents reported difficulty sourcing low-value fish in June, 27 (93 percent) in July, and 23 (93 percent) in August. This corresponds to the fishing ban from June to August. The majority of respondents 27 (93 percent) reported variations in the quality of low-value fish. The respondents perceived the low-value fish to be of poor quality mostly during the months of the fishing ban, from June to August.

The price paid for low-value fish ranged from CNY2.5 to 13.0/kg (US\$0.38–1.95/kg) with an average price of CNY5.4 (US\$0.81/kg). The use of low-value fish usage ranged from 30 to 3 000 kg per farm per day, with an average of 945 kg/day. However, some respondents estimated daily usage based on their farm size with or without using any pellets, but some farmers also used pellet feed.

Some farmers (12 respondents, 41 percent) incurred no transport cost for low-value fish to their farms. Of those having to pay for transport, the cost ranged from CNY15 to 300/day (US\$2.25 – 45). The average transportation cost was reported at CNY70/day (US\$10.5).

The time taken for the farmers to prepare the low-value fish ranged from 1 to 5 hours a day. On average, the preparation time was 2 hours.

In total, 24.8 percent of the farmers used satiation feeding when using low-value fish. They believed that satiation feeding resulted in fast grow rates and minimal feed wastage. Only 4 (14 percent) of the farmers rationed the low-value fish, and fed at an average rate of 35 percent body weight per day, which they learned from printed extension materials.

Both species (orange-spotted grouper and red snapper) accepted the two types of feeds readily. In the case of the red snapper, the farmers found that when pellet feed is mixed with a small quantity of minced fish the intake improves significantly. From environmental and economic perspectives, the farmers realize the need and the importance of using pellet feeds.

The majority of surveyed farmers in China (20 farmers 70 percent of respondents) believed that it is not harder to train fish to take pellets than to take low-value fish. The other 9 (30 percent) respondents believed it is harder to get the fish accept to pellets.

With respect to fish growth, 12 respondents (41 percent) believed that feeding low-value fish produces better growth than feeding pellet feed. Other farmers, (9 respondents 31 percent) believed that feeding low-value fish produces a better quality fish. Their quality criteria were of small fish growing fast, fish having good colour (3 respondents), and fish having good taste (1 respondent).

On pellet feed. To some degree, pellet feeds in combination with low-value fish were used by almost all the farmers. Farmers in China are well aware of the pros- and cons of the use of the two feed types. Currently the pellet feeds used for orange-spotted grouper and red snapper are the same (a floating pellet). There are two feed manufacturers in Zhanjiang specializing in feeds for finfish mariculture.

The majority of farmers (23 respondents, 79 percent) believed that feeding pellets is profitable and most surveyed farmers (26 respondents, 90 percent) found pellets readily available. The average price paid for pellets was CNY7.6/kg (US\$1.14/kg). There are six companies supplying pellets, the Evergreen Company is the major supplier. Pellet feeds for pompano, cobia, red snapper and grouper are commercially available.

Most farmers were willing to use more pellet feeds provided that species-specific feeds, and more pellet sizes were made available. Pellet feeds were readily available in most cage culture areas, but for example, they were not specific to groupers. The non-specificity of the available feeds discouraged farmers from using pellet feeds. However, all of the surveyed respondents (29 respondents, 100 percent) were willing to use pellets.

On microcredit. Some farmers have taken out loans, mostly from banks, which were also the credit source preferred by a majority of the farmers surveyed. Almost a third of the surveyed farmers (9 respondents, 31 percent) had used microcredit schemes banks. Six farmers reported using credit for buying low-value fish, pellet feeds and for cages and farm infrastructure. One farmer used credit for buying low-value fish, and another for buying fingerlings. Five of the 9 famers using microcredit found it useful, the other 4 respondents considered it not much use to their businesses.

BOX 1

Selected comments from the surveyed marine fish cage farmers in China that illustrate specific issues and suggested areas of assistance

- Marine aquaculture has a great potential. In the future, farmers will have to use more and more pellet feed for fish culture. We request feed manufacturers to produce feeds that are suitable for different species. This would help reduce production costs.
- We must improve feed continuously, and produce feeds that produce the best growth in each culture species, reduce FCRs and production costs.
- Establish as soon as possible the standard protocol for better management, train farmers to feed fish scientifically, reduce feed waste, reduce diseases, increase fish survival rates and improve profitability.
- Government agencies can provide effective disease control assistance and advice.
- We hope to get more technical support from government and feed manufacturers.
- Speed up research on feeds for marine finfish.
- Why low-value fish is still being used? (a) Farmers can obtain low-value fish easily, (b) for many species, there are no specific feeds produced for the species, and feeding pellet produces results that are not as good as when low-value fish are fed, (c) low-value fish has high content of protein and fish oil.
- To reduce use of low value fish there is a need to (a) improve the quality of pellets, increase number of feed varieties and types to suit different fish species and reduce feed costs, (b) find other ways to use low-value fish effectively, (c) government should establish production models and demonstration sites, (d) extension stations should be more active.
- The profits from marine fish culture are not very high, although they are good enough to support a family. Net income is not much and farm households often face difficulties in terms of cash flow. Fish culture provides employment for many people, especially during times of economic crises. We hope that the relevant government agencies pay more attention to the sector, and provide support to farmers with favourable policies, such as the provision of credit at low interest rates.
- My farm is located in the area near to processing plants. Due to their effluent, the sea water quality fluctuates. I suggest that the relevant government agencies periodically monitor the water quality.

The small size of the loans discouraged the farmers from availing the credit schemes, which they complained were inadequate to meet their needs. Other problems associated with the use of the microcredit schemes were the length of time and the effort it took to obtain the loans. Some respondents also considered the interest to be too high. Most of the surveyed farmers preferred to borrow from a bank (22 respondents, 76 percent), 6 respondents (21 percent) were unsure and 1 respondent preferred “other” credit sources. Regarding the application methods for microcredit, most respondents preferred an application form (19 respondents, 66 percent), with some preferring to present a business plan (5 respondents, 17 percent). Others were unsure (5 respondents, 17 percent) of their preferred method, and 1 respondent said he preferred to use other methods.

3.2 Indonesia

The respondents were 26 marine cage farmers in the broader Lampung area of Indonesia. The survey was carried out in July 2010. All the farmers in the area grow grouper species. The main species cultured in the Lampung area are the *Epinephelus* species of grouper, barramundi, golden trevally and humpback grouper. Of the surveyed respondents, 21 farmers (68 percent) cultured grouper, 2 farmers (6 percent) cultured barramundi, 3 farmers (10 percent) cultured golden trevally, and 5 farmers

(16 percent) cultured humpback grouper. All farmers grew some species of grouper. The number of cages that were operated by the farmers ranged between 8 and 500, with an average of 52.6 cages per farmer.

On low-value fish. The majority of farmers (25.96 percent) found it difficult to source low-value fish. The times during which accessing supplies was a problem were during full moon, religious festivals, bad weather, and the monsoon transition.

The quality of low-value fish was found to be variable by 19 respondents (73 percent), and it was difficult to predict when the poor quality fish was in the market. The average price of low-value fish was IDR4 774/kg (US\$0.54/kg) and ranged from IDR3 000–7 000/kg (US\$0.34 – 0.79).

Usage ranged from 20 to 4 000 kg/day with an average of 257 kg/day. This equates to an average of 3.6 kg of low-value fish per cage; the range was 0.9 to 13 kg of low-value fish per cage.

About half of the surveyed farmers (14 respondents, 54 percent) incurred no cost for transportation of the low-value fish. Those farmers incurring a transport cost paid between IDR15 000–100 000 a day (US\$1.69–11.24/kg a day). On a per kilogramme of low-value fish basis this equates from IDR150 to IDR1 071 per kg (US\$0.017–0.12) with an average of IDR489 per kg (US\$0.05/kg) for low-value fish transport.

The on site preparation of trash fish took between 1 hour to a whole day with an average preparation time of 3.1 hours/day.

Only ration feeding was reported by the surveyed farmers in Indonesia. The reported ration rates for low-value fish were between 3.5 and 7 percent of body weight per day, with an average of 5 percent of body weight per day.

On pellets. Pellet feeding, is not a new practice among the marine finfish farmers in Bandar Lampung. The majority (19 respondents, 73 percent) believed that it was harder to get fish to accept pellets than low-value fish. Some use pellets exclusively in the early years or in combination with low-value fish prior to the project trials being undertaken. All respondents believed that feeding low-value fish produces better results in terms of growth, health and the fitness of the cultured fish than feeding pellets. However, the farmers generally believe the use of pellets only result in lower growth performance in the larger fish (>150g) but not in the smaller fish.

Of the 26 respondents, 25 reported that pellets were readily available, however only 5 (20 percent) believed that feeding pellets was profitable. The pellet prices paid by the farmers ranged from IDR14 500 to IDR16 500 per kg (US\$1.63–1.85/kg). The average price for grouper pellet feeds was IDR15 217/kg (US\$1.71/kg) (US\$1.0 = IDR8 900). Although 24 of the 25 farmers reported using pellet feeds, they also reported using low-value fish.

Farmers reported using pellet feeds during periods when low-value fish were in short supply or were being sold at high prices. There was the perception that the grouper that were only fed pellet feeds had a lower health status or fitness, and that resulted in a low survival rates when the fish were transported to market. However, in other countries where other species were cultured, it was found that purging or starving fish for a day or more prior to transport, or feeding with low-value fish for a week prior to transport, alleviates this problem, and in addition, it may also improve body colour.

There was also the perception that the quality of the available feed could be improved, and that trials comparing the feeds that are specifically designed for grouper species would be beneficial.

On microcredit. The majority of the farmers (22, 88 percent) have used microcredit for funding capital infrastructure (e.g. cages) and operational costs (e.g. low-value fish). All the farmers believed that access to microcredit helped their businesses. However, some

Fish harvesting device in Lampung Bay, Bandar Lampung, Indonesia. A light inside the device attracts the fish and a fixed lift net is periodically lifted to harvest the fish. These devices are commonly used to harvest low-value fish for grouper cage farming in this bay.

Courtesy of FAO/Mohammad Hasan



farmers reported problems associated with using the microcredit. These issues including the loan amount being too small (2 respondents), high interest rates (5 respondents), the difficulty and long time taken to obtain the loans (5 respondents), the collateral requirements (1 respondent), and risky (1 respondent).

Banks were the preferred source for obtaining microcredit (11 respondents). All the respondents reported that presenting a business plan was their preferred application method to obtain microcredit.

3.3 Thailand

The survey was undertaken in June 2010 and covered 36 marine cage farmers in Southern Thailand. Four farmers were from Phang Nga, 14 from Phuket and 11 from Krabi. The majority of the marine cage farmers in Southern Thailand culture grouper species (34 respondents, 94.4 percent). The other species that are cultured include red snapper (10 respondents, 27.8 percent), barramundi (23 respondents, 63.9 percent); cobia, trevally & mussels (6 respondents, 16.7 percent), grouper/red snapper (10 respondents, 27.8 percent), grouper/barramundi (22 respondents, 61.1 percent). With the exception of one farmer who only raised cobia, all the farmers reported rearing more than one species. The surveyed farmers had on average 25 cages with individual farmers' cage numbers ranging from 5 to 140 cages.

On low-value fish. The majority of the surveyed farmers reported difficulty in sourcing low-value fish (32 respondents, 88.9 percent) and that the quality of the fish they had access to was variable (30 respondents, 83.3 percent). Those times in which the farmers reported difficulties in sourcing low-value fish or fish that was of a poor quality were during the monsoon season, the closed fishing season and the periods when catches were low.

The price farmers paid for low-value fish ranged from THB5/kg to THB15/kg (US\$0.17 to 0.50 per kg) with an average price of THB10/kg (US\$0.33/kg). Three surveyed farmers reported that they used fish processing waste as a feed. The cost of the processing waste was THB5/kg (US\$0.17/kg).

The quantity of low-value fish used was between 10 to 300 kg/day. On average, farmers fed 58 kg/day. This level of consumption equates to an average of 3.8 kg of low-value fish per cage per day (range: 0.45 to 20 kg low-value fish per cage per day).

Some farmers reported that they did not incur any transportation costs delivering the low-value fish to their farms (3 respondents, 8.3 percent) while others reported transport costs of between THB30 to THB1 300/day (US\$1–43.33/day) with an average of THB348/day (US\$11.6/day). On a per kilogramme basis, the transport cost ranged from THB0.3 to THB20/kg (US\$0.01 to 0.67/kg), and averaged THB8/kg (US\$0.27/kg). The time spent for preparing the low-value fish ranged from 1 to 4 hour/day, and averaged 2 hour/day.

The farmers used satiation, ration feeding or a combination of the two. However, most farmers (18 respondents, 64.3 percent) reported that they used ration feedings, 6 (21 percent) respondents reported using satiation feeding, and 4 respondents (14.3 percent) reported using both methods.

On pellet feed. The majority of the respondents (26 respondents, 72.2 percent) believed that it is harder to get fish to accept a pellet feed than low-value fish. About half of the farmers surveyed thought that feeding low-value fish produced better growth than feeding pellets, and 16 respondents believed that feeding low-value fish produced a better quality fish.

Generally, the farmers (21 respondents, 72.4 percent) believed that feeding pellet feeds was profitable. However, most (32 respondents 88.9 percent) of the farmers reported that pellet feeds were unavailable. The reasons for the preference for pellet

feeds included: savings on preparation time, better growth, longer storage times, improved nutrition, ease of management, convenience, consistent supply, and reduced disease.

On microcredit. The surveyed farmers borrowed from microcredit sources for a range of purchases including farm structures such as the cages and the materials to build the farm house (18 respondents 78 percent), low-value fish (2 respondents) and fish seed (3 respondents). They borrowed from banks (12 respondents), cooperatives (2 respondents), village funds (2 farmers), relatives (2 respondents) and a non-government organization (1 respondent).

The farmers' problems with the microcredit schemes included: loan amounts being too small (12 respondents), high interest rates (5 respondents), the long time taken to obtain the loans (5 respondents), a lack of collateral (1 respondent), and "not ready" (1 respondent).

The preferred source for accessing loans were banks (21 respondents), and the preferred methods of applying for microcredit were primarily the presentation of a business plan (15 respondents) or filling out an application form (11 respondents). One farmer indicated that he preferred applying for loans as a member of a farmer group.

3.4 Viet Nam

In July 2010, thirty marine cage farmers were surveyed in the Nha Trang area of central Viet Nam. The cage farmers in Nha Trang grow a combination of species, the most common being lobster, cobia, red snapper and groupers. The number of surveyed farmers culturing the different species was as follows: lobster - 25 farmers (84 percent); cobia - 20 farmers (67 percent); pompano - 11 farmers (37 percent); red snapper - 8 farmers (27 percent); groupers - 5 farmers (17 percent); other fish species - 5 farmers (17 percent). Most farmers grew more than one species. Three farmers only cultured cobia, and one farmer only cultured lobster. The surveyed farmers operated between 2 to 70 cages per farmer. An average 28 of cages were used per farmer.

On low-value fish. Most farmers (27 respondents, 90 percent) reported that it was difficult to obtain low-value fish for most of the year, the exception was between March and June. Most farmers (26 respondents, 93 percent) also reported that fish quality was variable and poor during the times when supplies were difficult to access. Prices ranged from VND5 000–15 000 per kg (US\$0.26–0.79/kg) with an average price of VND7 730/kg (US\$0.41/kg).

The quantity of low-value fish used by the farmers ranged between 20 to 180 kg/day (average: 87 kg/day); this equates to an average of 3.55 kg of low value fish per cage per day, or a range of 0.94 to 10 kg per cage per day.

Some farmers (8 respondents, 27.5 percent) incurred no cost in transporting their low-value fish to their farms; others paid between VND20 000–100 000/farm/day (US\$1.05–5.26/farm/day). On average, the farmers spent VND 49 500 /farm/day (US\$2.61/ farm/day) for transporting low-value fish. On a per kilogramme basis, this equates to an average of VND1 000 per kg (US\$0.05/kg). For individual farmers the transport cost ranged between VND230 and VND5 000 per kg fish (US\$0.01–0.26/kg)

Preparing the low-value fish took between 2 to 4 hours a day. The surveyed farmers employed either satiation or ration feeding, with the majority feeding to satiation (16 respondents, 61 percent).

More than half (15 respondents, 58 percent) of the farmers believed that it was harder to train the fish to accept pellet feeds than low-value fish. Generally, the farmers also believed that feeding low-value fish produces the better growth (24 respondents 89 percent), and improves the quality of the fish (18 respondents 68 percent) than feeding pellets.

A number of people make a living from transporting or supplying low-value fish to the cage farmers. When interviewed, they indicated that they were not concerned about the livelihood implications associated with the farmers changing from using low-value fish to pellets, and indicated that should farmers cease using low-value fish, they would be able to find alternative livelihoods.

On pellet feed. Despite the perception that using pellet feeds produces slower growth rates and results in poorer quality fish, the farmers generally believed that feeding pellets was profitable (22 of the 25 respondents, 88 percent). While some farmers reported supply issues (13 of 24 farmers, 54 percent), almost all of the farmers (28 of 29 respondents) reported that if pellets were readily available they would use them.

On microcredit. The majority of the farmers (81 percent) have previously accessed microcredit. These loans were used to: purchase of low-value fish (18 respondents), farm infrastructure (16 respondents), purchase fingerlings (six respondents), and to purchase pellet feed (6 respondents). Most of the farmers (17) obtained their loans from banks, but some reported borrowing from relatives (3 respondents). The farmers indicated that the high interest rate (11 respondents) was the main problem with microcredit. Others complained of the difficulties in obtaining loans (6 respondents), and the inadequacy of the amount they could borrow (4 respondents).

Sixteen of the 17 farmers surveyed indicated that they preferred to borrow from a bank. The preferred application methods to obtain credit were (i) a business plan (7 respondents) followed by (ii) an application form (5 respondents).

VI. Environmental impact study

1. RATIONALE

Due to the high feed conversion ratios associated with the use of low-value fish, it is a contentious issue both from a resource use view point and an environmental integrity perspective. Feed type, quality and feeding strategy have major influences on the environmental impact associated with shore-based and open water farming systems. Excess nutrients that are not utilised by the fish are released into the environment and have to be assimilated, alternatively they cumulate. Whether a nutrient becomes a pollutant in an aquatic system is a function of whether it is a limiting nutrient in a given environment, its concentration, and the carrying capacity of that ecosystem. The excess nutrients are released into the environment in two forms, dissolved nutrients and particulate nutrients.

The practical purpose of the study was to compare the impacts of feeding low-value fish and pellet feed on the immediate culture environment, that is, the waters beneath and around the cages, and to develop information to demonstrate the environmental benefits of using pellet feeds. The scope was extended to cover two other indicators of environmental impact: the energy embodied in one kilogramme of feed material, and the amount of fish that is required to produce a kilogramme of fish (fish-in fish-out ratio or FIFO).

2. SUMMARY OF FINDINGS⁵

The environmental assessment results showed that that in terms of feed type, there was no significant measurable difference in impacts associated with dissolved nutrients (N and P, NH₃), and dissolved oxygen or impacts to sediments. This may have been due to the low stocking densities used in the farm trials. Higher stocking densities and input levels may have shown different results. The trial cages were located among other cages that were fed with pellets and low-value fish, and thus it was not possible to distinguish the impact of fish fed with pellets from that of the fish fed the low-value fish. The impacts measured therefore are the impacts associated with a number of cages fed a combination of pellets and low-value fish.

The study specifically found that:

- 1) There was no significant difference in the environmental impacts associated with the cages fed either the low-value fish or the pellet feeds.
- 2) The choice of culture species did not significantly affect the environmental impacts associated with the use of aquafeeds.
- 3) There were increases in bacterial loading in trash fish that was stored on ice before feeding, and an increased bacterial release to the culture waters when feeding 2- and 3-day old trash fish/low-value fish.
- 4) Generally there was more nutrient leaching into the water column associated with the use of pelleted feeds than with the use of trash fish/low-value fish.
- 5) The energy cost of producing one kilogramme of farmed fish was significantly lower with low-value fish than with pellet – when the low-value fish was harvested by small boats in artisanal fishing; it was higher when fish was caught by commercial trawlers.

⁵ The details of the methodology and findings can be found in the full report, which is Annex 2.

- 6) The fish-in fish-out ratio (FIFO ratio) for the production of a unit weight of fish using pellet feed was almost two-thirds lower (3.34:1) than using trash fish/low-value fish (9.02:1).

2.1 Technical considerations

2.1.1 Dissolved nutrients

Soluble nutrients derived from the digestion processes of farmed fish dissolve in the water column and their dilution and transport is a function of water current dynamics. Dissolved nutrients are 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, algal blooms, or both.

Eutrophication, low oxygen events and fish kills affecting local fisheries and fish cage production are common events in some lakes and reservoirs in Asia, particularly where there is a high density of small-scale cage farms that together produce excess nutrients in dissolved and particulate form that extend beyond the carrying capacity of the water body.

The most important factors determining the impact of fish farming on water column nutrients, water quality, and pelagic ecosystems are: the loading rate of inorganic nutrients, especially nitrogen in marine systems; the local hydrodynamics and depth at the cage sites; the degree of exposure of bays and the near-shore coastal areas in terms of water replacement; the stocking density and FCRs attained; the density of the fish farms.

Of these factors, the hydrodynamic characteristics of the water body is the most important driver affecting the impact that nutrients have on the water quality. The impact of a large farm or a large number of small farms located in an enclosed water body, characterized by static hydrodynamic conditions, will have a larger impact on the water quality, than the same farm or farms being located in more open or exposed sites where the hydrodynamic conditions are more dynamic. The latter will produce less severe impacts, but those impacts will be diffused over a wider area.

Excess inorganic nitrogen and phosphorus from fish cages is available immediately for phytoplankton uptake. Sites with low flushing will exhibit increased phytoplankton biomass with peak soluble nutrient loadings.

2.1.2 Sedimented nutrients

Solid waste comprising uneaten feed pellets, feed fines (fine particulates caused by pellet damage during transport or the use of automated feeding systems), and faecal material can also accumulate below culture cages and in the outflows of aquaculture facilities. Particulate nutrients settle and are assimilated by sediment benthos flora and fauna. If particulate nutrients are in excess of the assimilation capacity, then they will accumulate. The accumulation of nutrients may also affect the level of biodiversity in the area, and in extreme cases cause anoxic conditions to form. Anoxic condition may kill organisms in the sediments. The accumulation of nutrients will also depend on the local currents and depth. Organic sediments can also impact benthic (e.g. seagrasses) and sensitive habitats such as corals close to the farm. These areas may be important as a food source or habitats for local wild fisheries.

A high FCR means, less of the nutrients in the feed is taken up by the fish, and thus more will be released into the environment. Improvements in FCRs will reduce nutrient impacts in the vicinity of the cages. In this regard, reductions in feed loss and improvements in nutrient conversion efficiency will improve FCRs. The FCR is also affected by fish size, water temperature and fish health status.

3. METHODOLOGY

Baseline data on cage positions, currents and bathymetry were collected from the project fish farms in Nha Trang, Viet Nam (10 farms), Phuket, Thailand (5 farms), and

Bandar Lampung, Indonesia (5 farms). The procedures and the results are summarized in this section; the details are presented in Annex 2.

Cages were mapped using a Global Positioning System. Farms in Viet Nam were clustered in one area whereas the farms in Indonesia and Thailand were situated in different locations.

3.1 Current speed, direction and dispersion

Current speed, direction and dispersion indicate water exchange and mixing at the cages, and are the most important factors influencing cage farming related environmental impacts and production carrying capacities. The current direction was determined using drogues at a depth of 5 metre (for deeper waters) and 2 metre for shallower waters. In open waters, the current speed varied between 2.16 cm/sec in Viet Nam, to 5.46 cm/sec in Indonesia. In estuarine waters in Thailand, the water flow was much faster at 38 cm/sec.

3.2 Current dispersion

Current dispersion is a measure of the mixing of the water column, and reflects the dilution of nutrients derived from the fish farm in the receiving water body. The dispersion ranged from 0 in one site in Indonesia, to 33.8 percent/min in Thailand. The estuarine site in Thailand, where higher current speeds were recorded, also recorded higher dispersion rates of 1 985 percent/min.

3.3 Bathymetry

Water depth (bathymetry) was recorded using a hand held echo sounder at the corner of the project farms, reference sample sites, and drogue readings. The bathymetry varied between 3–5 metres depth in the estuarine site in Thailand, and between 8 to 25 metres in the open sea sites.

3.4 Water quality

Water quality is influenced by a number of factors including the speed of the water current at the time of sampling, and the time that the sample was taken after feeding. Therefore nutrient loading may vary. Generally it is a short term impact as the nutrients are quickly assimilated by algae and plankton. However, if water exchange is poor it can lead to eutrophication.

Water samples were collected and the following parameters recorded: temperature, pH, salinity, turbidity, dissolved oxygen and ammonia. In some cases, additional parameters were also collected and analyzed. These parameters including nitrite, nitrate and plankton. Each parameter was measured next to the cage, or inside and outside of the cages. Samples were also collected from an un-impacted reference location. The location of the sampling points is presented in Figure 1.

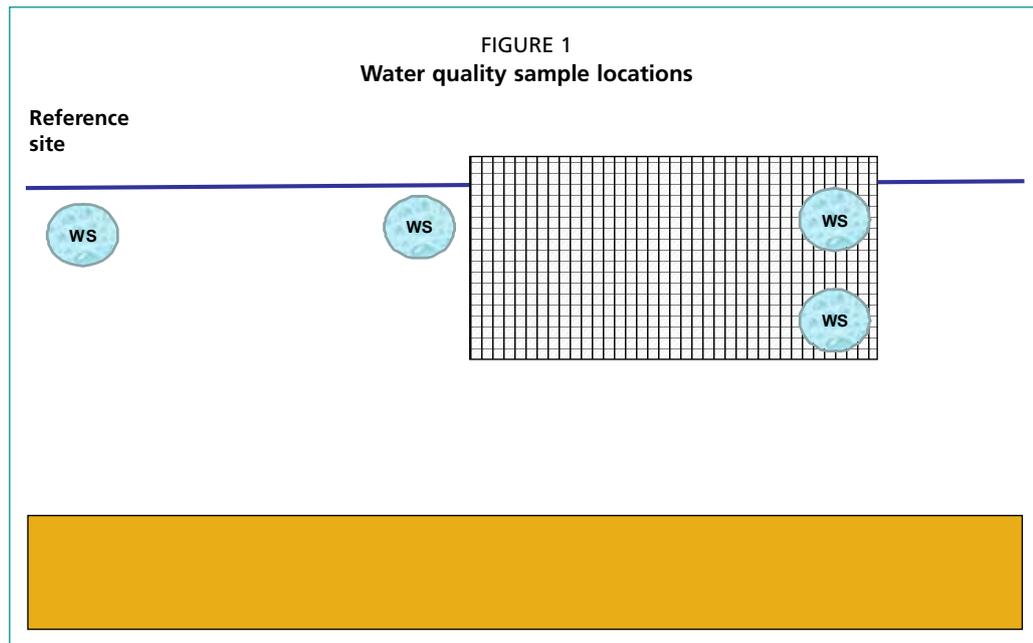
4. RESULTS

The findings from each parameter are summarised below. Detailed descriptions of these findings are presented in Annex 2.

4.1 Water Quality

The water quality results were similar for each of the case studies. There was very little water quality difference between

- inside and outside of the cages
- the top and the bottom of the cage
- cages that were fed pellet feeds or low-value fish
- cages with different fish species



Nevertheless, water quality differed over the culture period, reflecting ambient water quality conditions, and the increasing biomass of fish within the cages.

4.2 Dissolved oxygen

In Viet Nam, dissolved oxygen concentrations did not differ significantly between the samples collected from the surface, bottom or outside the cages or between the samples collected in cages with grouper or pompano. However dissolved oxygen levels did differ during the culture period, decreasing rapidly between June and August.

In China, dissolved oxygen concentrations did not differ significantly between samples collected from the surface, bottom or outside the cages or between the samples collected in cages with orange-spotted grouper or red snapper. However dissolved oxygen levels did differ during the culture period, increasing rapidly between June and October.

In Thailand, dissolved oxygen concentrations did not differ significantly between the samples collected from the surface, bottom or outside the grouper and seabass cages.

In Indonesia, dissolved oxygen concentrations were only measured inside the cages. There were significant variations in the oxygen levels in the cages; however these variations were primarily due to the farms being located in different areas of the bay.

4.3 pH

In Viet Nam, pH concentrations did not differ significantly between the samples collected in cages with grouper or pompano. However, pH differed during the culture period increasing between April and August, and decreasing slightly between September and November.

In China, pH concentrations did not differ significantly between the samples collected in cages with orange-spotted grouper or red snapper except for the penultimate three samplings. However, the temporal variation of pH was observed during the culture period, decreasing in October.

In Indonesia, pH was only measured inside the cages. pH was relatively constant, and was recorded at between 7.8 and 8.3. This is well within the recommended levels of 7 and 8.5 for marine finfish.



Measurement of turbidity (Secchi depth) using a Secchi disc in Nha Trang Bay, Viet Nam.

Courtesy of FAO/Patrick White

4.4 Ammonia

In Viet Nam, ammonia concentrations differed significantly between samples collected inside and outside the cages with snapper and pompano.

In Thailand, ammonia concentrations differed over time in tiger grouper and barramundi cages. There was an increase in ammonia concentrations just before harvest in the barramundi cages; however, this was not the case in the grouper cages. The ammonia concentrations did not significantly differ between the inside and the outside of the cages of the fish that were fed pellet or low-value fish feeds.

In Indonesia, ammonia concentration was only measured inside the cages. Ammonia concentrations peaked during September and October 2010. During this period and in some cages, ammonia concentrations exceeded the recommended maximum levels for marine finfish. These ammonia levels were much higher than any of the other levels recorded in the other countries. In Indonesia, additional water quality parameters (e.g., nitrate, nitrite and phosphate) were measured inside the cages. Water quality changed over time, but with the exception of one farm, there were no significant differences between the farms.

Each data set from each case study country was tested of normality and homogeneity. Both assumptions were met for the water quality variables of interest. Statistical analyses were then undertaken, and the only significant statistical differences ($P < 0.05$) found were as follows:

- Viet Nam – the water quality in the snapper and pompano cages only differed with respect to the ammonia concentrations inside and outside the cages.
- Thailand – there were significant differences observed between stations for nitrate and nitrite.

None of the water quality parameters differed significantly across the feed types in China and Indonesia.

4.5 Comparison of nutrient discharges

No significant differences were found in the water quality parameters between the cages in which the fish were fed either pelleted or low-value fish diets. In the absence of measurable differences in the water quality parameters, estimations of the theoretical differences in nutrient input and output were made using nutrient flow analysis. On a wet weight basis, pellet feed has a higher total phosphorus and nitrogen content than low-value fish. However, it should be noted that pellet feed comprised only 10 percent moisture content whereas low-value fish comprised 75 percent moisture. If the calculation was made on a dry weight basis, the total phosphorus concentration is similar, but the total nitrogen concentration in low-value fish is higher.

4.6 Sediment quality

Organic loading of the sediment takes place over time and therefore is a long term indicator of impact. Benthic sediment samples were collected close to the cages and at a reference site either by van Veen grab for hard sediment conditions or corer for soft sediment conditions. A characterization of the sediment was made as follows:

- sediment type – shell hash, gravel, sand, or mud (silt and/or clay);
- surface colour and colour change with depth – as a possible indicator of oxic or anoxic state;
- smell – sulphide (the odour of H_2S or rotten eggs), oily (the odour of petroleum tar), or humic (a musty, organic odour). Typically, un-impacted sediments will have no particular odour;
- general sediment colours – black, green, brown, red, yellow.

While samples that were black and had a strong sulphurous smell and were devoid of fauna indicated that they had been collected from highly impacted areas, samples that showed high levels of indicator species such as polychaetes (e.g. *Capitella capitata*)

also indicated a high levels of impact. Samples that had a wide number of different phyla (mollusc, crustacean, polychaete etc) indicated limited or no impact.

The analysis of the sediment samples revealed that there was a wide range of species in the sediments, and that they were not dominated by polychaetes or indicator species. This indicates that there were low impacts associated with the sediments below the cages, and furthermore that there were no measurable differences in the impacts accruing to the use of either the low-value fish or pellet feeds.

4.7 Stocking density

Typically the stocking densities in the trial cages were low. Cages of 3m x 3m x 3m with a total volume of 27 m³ were stocked at a density of 2.6 kg/m³. This gave a stocking density of 7.7 kg/m².

At this density, the environmental impacts between the farming activities would in all likelihood be minimal or low. However at commercial production levels, 3m x 3m x 3m cages fed pellet feeds would typically have a holding biomass of 10 to 15 kg/m³. This would give a stocking density of 30 to 45 kg/m² (cage surface area). At these densities, the environmental impacts between the farming activities are likely to be high.

4.8 Overfeeding

One of the greatest influences on the amount of excess nutrients entering the environment is poor feeding strategy, which results in overfeeding. In this regard, farmers can improve their FCRs by providing the correct feed amount, optimising feeding periods, frequency, and timing.

A test was made to determine the level of over feeding by the farmers in Viet Nam and Thailand. The farmer was asked to use feeding tray and weigh pellets that would typically be used in a feed round, and subsequently feed the fish normally. After the feed rounds had been completed, the trays were recovered and the number of uneaten pellets counted. It was estimated that the farmers had been overfeeding by 11.2 percent.

4.9 Pathogen transfer

Both cultured and wild fish are susceptible to similar pathogens and parasites. Intensive culture conditions can increase their prevalence in the culture populations significantly. There is a risk of pathogen transfer to the cultured fish from feeding low-value fish that are infected with bacterial diseases. Therefore it is recommended that prior to use, samples of the low-value fish that is used as feed are screened for pathogens.

A test was undertaken in Indonesia to determine the bacterial loading (total bacterial counts per gram of sample) of low-value fish and pellet feed samples that had been stored on ice for a number of days. It was established that there were significantly higher bacterial loadings in the low-value fish than pellet feed, and that these bacterial loading increased over time.

4.10 Trash fish/low-value fish quality

In Viet Nam, three qualities of trash fish were available to the farmers. The quality and price was determined by species composition, quality and freshness, as follows:

- low quality trash fish at VND5 000/kg (US\$0.24/kg)
- medium quality trash fish at VND7 000/kg (US\$0.34/kg)
- high quality trash fish at VND9 000/kg (US\$0.43/kg).

In Indonesia, the trash fish was delivered to the farmers every three days. On arrival at the farm, the fish was placed in insulated tubs with ice and held until feeding – usually for a period of one to three days.

At some farms, the trash fish undergoes some minimal forms of processing. The type of processing depends on the target species, and the trash fish are either fed as:

- whole trash fish
- trash fish body (not including the head or tail)
- trash fish without the stomach
- a combination of trash fish and fish processing waste (heads and tails).

4.11 Bacterial levels in water column

In Indonesia, a comparative trial was undertaken to measure the bacterial levels in water column when either trash fish (stored on ice) or pellet feeds that had been stored for an increasing length of time were fed to the fish. The trial examined the bacterial loading in the water column when different qualities of trash fish (1-day, 2-day, and 3-day old) and pellet feeds were fed. The results demonstrated that in comparison with the use of pellet feeds, the use of trash fish significantly increased bacterial levels in the water column, and that bacterial levels increased as a function of the time that the material was in the water, and the time that the trash fish had been stored prior to use.

4.12 Nutrient leaching to the water column

In Indonesia, a test was undertaken to measure nutrient leaching (NH_3 , NO_2 , NO_3 and PO_4) in the water column. The leaching properties of three different qualities of trash fish/low-value fish (1-day, 2-day and 3-day old) and pellet feeds were established.

The results showed that in contrast to feeding pellet feeds, there were significantly higher ammonia ($\text{NH}_3\text{-N}$) levels in the water when trash fish were fed, and that the levels (leaching) increased after the 2nd day of storage, and subsequently decreased after the 3rd day of storage. The pellet feed leached significant amounts of nitrite ($\text{NO}_2\text{-N}$) in the water column. Nevertheless, the trash fish that had been stored for one day released the highest level of nitrite - these levels decreased after the 2nd and 3rd days of storage. Nitrate ($\text{NO}_3\text{-N}$) leaching was found to be significantly higher when pellets were immersed in the water for a period of one hour. In addition, the levels of nitrate observed from the trash fish that had been stored for one day and left in the water for a one hour period were elevated above those samples that had been stored for two or three days.

There was higher leaching of phosphate ($\text{PO}_4\text{-P}$) from pellets which remained in water for 1 hour but less from pellets that remained one minute. In terms of the phosphate leaching from the trash fish, the level of leaching was slightly higher in those fish that had been stored for one day. Increasing the storage period to two and three days reduced the level of leaching.

4.13 Energy use

The energy required to produce aquafeeds varies between feed type (trash fish/low-value fish or pellets) and manufacturing processes. The reported energy use to produce pellet by EWOS, Norway was 1 040 MJ/tonne feed produced (Cermaq, 2009). In contrast, the Thai Union aquafeed production plant uses only 99 kilowatts per tonne of feed produced - equivalent to 356.4 MJ per tonne of feed produced (Supis Thongrod, Thai Union Feed Mill Co., Ltd., personal communication, 2010).

In addition to the energy that is expended during the manufacture of the pellet feeds, there are many additional activities and processes that require energy. These energy requirements include the energy expended in:

- pelagic fishing;
- fishmeal production;
- transport of the raw materials to the feed producer; and
- transport of the finished products to the farms.

It has been estimated that the total energy used to produce 1 tonne of pellet feeds is 18 100 MJ (including transportation costs). Using pellet feeds, and assuming an FCR for pellet is 2.45:1, then the energy used for feed to produce 1 kg of fish is 44.35 MJ.

The energy required to supply low-value fish to the farmers can be calculated in a similar way. The energetic costs associated with fishing for trash fish in Thailand and Indonesia and the production of pellet feeds in Thailand and Viet Nam was assessed. An estimate of the total energy expended for the different processes in trash fish supply chain was made. Applying the FCRs from the feeding trial, the following estimates of energy used to produce one kilogramme of fish were made:

Thailand: FCR 11:1 at 0.36 MJ/kg = 3.96 MJ used to produce 1 kg of fish.

Indonesia: FCR 6:1 at 13.58 MJ/kg = 81.48 MJ used to produce 1 kg of fish.

It is evident that depending upon feed type and source, there are significant differences in the energy required to produce one kilogramme of fish. In Thailand, using a small dedicated boat for catching trash fish, 3.96 MJ was required to produce one kilogramme of fish. In Indonesia, this figure increased to 81.48 MJ when trash fish derived from commercial trawlers were used. In contrast, the use of pellet feeds in Thailand and Viet Nam required 44.35 MJ to produce one kilogramme of fish.

4.14 Fish-in Fish-out ratio (FIFO)

A long-running debate in the aquaculture sector is the use of fishmeal and fish oil in aquafeeds, the sustainability of use, and the amount of wild fish that is required to produce farmed fish. A number of different methods have been developed to calculate the amount of wild fish that it takes to produce one tonne of farmed salmon. One such methodology is based on the fish-in fish-out ratio (FIFO ratio). Using dry pellets, FIFO ratios for salmon range between 3:1 to 10:1. A FIFO ratio of 4.9:1 for salmon production would indicate that 4.9 tonnes of wild fish are required to produce 1 tonne of farmed salmon.

There are at least four different methodologies of calculating FIFO ratios, developed by Tilapia Aquaculture Dialogue draft v2.0 (WWF, 2009), Tacon and Metian (2009), International Fishmeal and Fish Oil Organisation (IFFO) (Jackson, 2009) and EWOS methodology for fatty fish such as salmon (EWOS, 2009).

As the marine fish produced in this study were not high fat species, the IFFO formula was adopted. The estimated FIFO ratio for tropical marine fish is as follows:

$$\frac{\text{Level of fishmeal in the diet} + \text{level of fish oil in the diet}}{\text{Yield of fishmeal from wild fish} + \text{yield of fish oil from wild fish}} \times \text{FCR}$$

The result: FIFO for pellet is 3.34:1, FIFO for trash fish is 9.02:1



Low-value fish harvested from Lampung Bay, Bandar Lampung, Indonesia.
Courtesy of FAO/Patrick White

VII. Livelihood analysis of low-value fish suppliers

1. RATIONALE

The fish suppliers – the fishers and traders in low-value fish - are important stakeholders in the marine cage culture sector. They play a major role in providing the dietary protein that enables the farmers to culture high-value marine finfish, and as such, they have had an important contribution in the expansion of the industry. As their livelihoods are linked with those of the fish farmers, a shift to commercial pellet feeds could pose a threat to their livelihoods. To address this issue, the project sought to assess: (a) the potential impacts that the farmers' switch from low-value fish to pellet feeds would have on their livelihoods, (b) their ability to cope with these impacts, and (c) the opportunities that are available to them should the changes in feed use occur. From a practical perspective, the purpose of this component of the study was to develop measures that would enable the fishers/fish suppliers to mitigate the impacts to their livelihood of farmers' changes in feed use, and facilitate or improve their alternative livelihood opportunities.

2. METHODOLOGY

Two principal activities were undertaken to obtain the livelihood information that was required for the analysis. The first, which was carried out before the farm trials were implemented, was a baseline survey of the livelihoods of the fishers and the suppliers of low-value fish. The second activity was a qualitative assessment based on the results of the baseline survey. This activity was undertaken in conjunction with the project activity to develop strategies to increase participation, enhance extension support and improve the livelihoods of people involved in cage culture activities. This component was carried out in two missions - during and after the farm trials. It was designed to assess the perceptions of the fishers, traders, fish farmers, spouses and farm workers in terms of the livelihood implications of the farmers' changing from trash fish/low-value fish to pellet feeds. The details of the baseline survey results and those of the qualitative assessment of changes in perception before and after the trials are presented in Annex 3.

2.1 Survey

The baseline survey of the livelihood status, prospects and strategies of fishers of trash fish/low-value fish showed basic differences between fisher households across the study countries. In China, the fishers use large vessels, and typically, fishing is almost always the sole source of household income. As a commercial scale activity it generated considerably higher revenues for the Chinese fisher households than those fisher households in the other countries. In contrast, the fisher households in Indonesia, Thailand and Viet Nam engaged in diverse activities to supplement their household incomes. In some cases, these alternative activities earned the households more income than fishing.

Between the countries, the livelihood patterns of the fisher households varied significantly. In a similar manner, their access to advice and assistance on fish farming and other livelihood activities also varied - these sources of advice and assistance were widely available and accessed in Thailand, and were least available in China. The fisher households overwhelmingly ranked as the most important strategies for securing their future the education of their children, and the accumulation of savings.

In China, the lack of alternative livelihood options for the fishers makes them vulnerable to an industry-wide shift to pellet feeds. In mitigation, their catch is geared towards supplying the fishmeal processors which represents an established market for them. While the fishers target food grade fish, these food grade species are becoming increasingly rare, and the main target species is now the lower valued ribbon fish. At present, the length of time that the trawlers stay on the offshore fishing grounds, and the mixing of silt with the fish (primarily a demersal catch) significantly degrades the quality of the catch, and thus a higher proportion is reduced to a low-value, poor quality product. A greater threat to their livelihoods than the change in feed use by the cage farmers, is the depletion of the fish resources in their current fishing grounds – particularly as fishing pressure is already intense with 10 000 trawlers operating in the area.

Generally the fishing households in all the four countries have a reasonable level of household assets, and they have a number of options that enable them to cope with a direct impact on their main livelihoods.

2.1.1 *Fishers' fears and outlooks*

There were two distinct outlooks for the fish suppliers, should their present customers switch to commercial feed. In China, the majority of the fishing boats landed a large proportion of low-value fish and sold their catch to the cage farmers. Understandably, the fishers were very concerned about the impact that a shift from low-value fish to pellet feeds would have on their livelihoods. The majority of the fishers supply their fish directly to the cage farmers, and receive a better price from the farmers than they would from the fishmeal processors. However, the loss of the farmer customers will simply reduce their incomes as they will be able to sell their products to the fishmeal processors, albeit at a lower price. However, the fishers fear that should the demand from the farmers be reduced, the fishmeal processors may see this as an opportunity to reduce their purchasing prices. The survey also revealed most of the Chinese fishers have no alternative livelihood options. In contrast, the fishers and fish traders in Indonesia, Thailand and Viet Nam have a number of options. As with China, the price offered by fishmeal producers in Thailand and Viet Nam is lower than those the farmers are usually willing to pay. The exception is Indonesia.

2.1.2 *Dependence on fishing*

The fishers' dependence on fishing provides an indication of their vulnerability to threats to their livelihoods. The threats would include the depletion of the fishery resources, the cessation of fishing, or decline in the demand for their products. Indicators that can be used to assess their dependence on fishing include their reasons for fishing, the importance of fishing income to total household income, the availability of alternative livelihood options, and livelihood assets owned or accessible to the fishers. The analysis can be used to inform policy, and develop programmes that are aimed at easing their transition from fishing to alternative livelihoods.

- **Reason for fishing.** Nine factors that influenced a households' decision whether to engage in fishing and supplying fish were assessed. Overall and across the countries, the respondents gave the highest ranking to “easy access to the fisheries resources”. Fourteen individuals ranked this factor as the most important factor in terms of their decision making processes, and it was chosen by 53 percent of the respondents. Most notably, 78 percent of the Thai fishers ranked this as their most important factor when choosing whether to enter the sector.
- **Importance of income from fishing.** Sixty one percent of the fishers surveyed across the trial countries indicated that fishing generated higher incomes than their other livelihood activities. In contrast, only 14 percent reported that other livelihood activities earned them more than fishing. Engaging in other activities

that generate household income was intrinsically related to their access (owned or leased) to land. Most of the Chinese fisher households did not own or lease land (apart from their dwellings), and even if they had, the commercial nature of their fishing activities would have afforded them little time to grow crops or raise livestock. In contrast, Thailand and Viet Nam fisher households owned or leased land which enabled them to earn additional income from agricultural activities such as growing cash crops, raising poultry, livestock, and fish.

- **Income generating activities other than agriculture.** Nearly 30 percent of the 91 fisher households that were surveyed were engaged in some form of non-agricultural, income generating activity. The largest number of non-agricultural livelihoods were reported from Viet Nam (43 percent) and lowest number was reported from China (10 percent – representing just one household). The livelihood activities ranged widely - from operating a convenience store to being an electrician. On average, these alternative livelihood activities accounted for 33.2 percent of total household incomes.
- **Household assets.** One household from Indonesia reported having 20 cattle, whereas four Vietnamese households reported having ten, eight, one, and two cattle each. The Chinese fisher households did not raise poultry or livestock. Indonesian households reported raising minimal numbers of animals, with only one household reporting having 20 cattle, and one rearing poultry. Nearly 43 percent of the Vietnamese households reported keeping poultry and 9 percent reported having cattle. Across the four countries 82 percent of the fishers reported owning the house in which they lived. The type of houses that were owned were durable, and of brick and concrete.
- **Institutional support.** Institutional support data could only be obtained from the surveys from Thailand and Viet Nam. In Thailand, farmers identified 26 local organisations, offices or programmes. In Viet Nam, this number was nine. The organisations in Thailand were diverse and included Non-Governmental Organizations (NGOs), whereas in Viet Nam, all the organisations that were identified were fishery related. The usefulness of these organisations to the households was qualitatively assessed. The most useful organisations and institutions in Thailand were the Provincial Fisheries Offices, the Fisheries Department, the Village Development Funds, and the Provincial Cooperatives. In Viet Nam, the Fisheries Union was ranked as the most useful organization.
- **Financial capital**
 - Savings.** Across the four countries, only 67 percent of the fisher households save money on a regular basis. The lowest number of fisher households that reported saving money was in China, where only 5 percent of households saved money on a regular basis. In contrast, 85 percent of fisher households in Thailand, and 88 percent of households in Viet Nam saved money. Bank savings and jewellery were the main forms of saving, accounting for 71 percent of saving across the countries.
 - Source of loans.** Nearly 75 percent of the fisher households reported borrowing money. The highest number of borrowers being in China (90 percent), and lowest number in Thailand (55 percent). Annual household incomes were highest in China. Loans were facilitated through a variety of sources, however, in all the trial countries bank loans predominated. Private money lenders provided a major source of loans in China and Viet Nam, and only one village fund in Indonesia was found to make loans to the fishers.

2.1.3 Coping with financial difficulty

When the fishers were asked how they would respond to unforeseen financial difficulties, the overwhelming response was to borrow money. The remaining options

that they were asked to assess were deemed relatively unimportant. These options included selling household assets, increasing fishing effort, ceasing to fish, looking for non-fishing work, reducing hired staff on agriculture operations (if agriculture is practised), requesting the family to assist in operating an aquaculture operation, removing the children from school, or reducing household expenses.

2.1.4 *Preparing for a secure future*

The fishers were asked how they would prepare for their financial future. The means considered were their children's education, continuous savings including providing contributions to a pension scheme, the simultaneous pursuit of several income generating activities as part of a diversification strategy, and placing an emphasis on subsistence activities for home consumption. Almost all the fishers placed the greatest importance on their children's education, followed by savings. Many households also indicated that the simultaneous pursuit of several income generating activities would be an important strategy to prepare for the future.

2.2 **Qualitative assessment**

A qualitative assessment of the changes in perceptions and attitudes of fishers and fish cage farmers before and after the trial was undertaken. The assessment was based on the baseline survey data, and two follow up visits that were undertaken during and after the end of the cage production trials. The purpose of the assessment was to assess the perceptions of the fishers, traders, fish farmers, spouses and farm workers on the implications accruing to the farmers' changing from low-value fish to pellet feeds on the livelihood of the fishers and traders. The methodology comprised meetings with some of the fishers who had been respondents to the baseline survey, farmer groups that included participating and non-participating farmers, individual farmers or farmers and their spouses. The country findings from these qualitative follow up assessments are summarized in the following section. The salient findings are presented in Annex 3.

2.2.1 *Findings*

The fishers and fish traders' initial fears of losing a market but not their livelihood remained unchanged. The fishers and fish traders had alternative clients in terms of the fishmeal processors, and in addition, the fish traders had access to a diverse range of commodities that they could trade. In both China and Viet Nam, the number of fishers selling their low-value fish directly to the fish farmers was low (7–10 percent) when compared to Thailand (60 percent) and Indonesia (75 percent). The average price paid per kilogramme of fish was lowest in China, followed by Indonesia. In Thailand and Viet Nam, similar prices that were higher than those of the other two countries were paid. There was also considerable price variation throughout the year. At the post trial assessment, some fishers expressed the need for assistance from government should they lose their market. While this was probably a predictable response, they do need assistance whether or not there is a switch to pellet feed by the cage culture industry.

2.2.2 *Findings by country*

1) *China*

Perspectives of fisher groups. Two groups of fishers were interviewed. They revealed there were few pelagic species left in their traditional fishing grounds. Their major target species was the demersal or bottom dwelling ribbon fish which is still relatively abundant. In the past, these were dried or salted and sold as food fish. However, a general rise in incomes has changed food habits and preferences, and there has been a reduction in the demand of dried / salted fish. On an annual basis, they estimated that they can only fish for an aggregate of six months. This is primarily due to the

many holidays and the lunar phases. Meeting household necessities when there was no fishing is difficult, particularly for the crew members - they have no land to cultivate, and have to find non-fishing employment elsewhere.

2) *Indonesia*

Fishing vessel owners and workers as well as the fish traders indicated that there would be no difficulty in selling the catch for human consumption or to the fishmeal factories. As payment is usually delayed when they sell to fishmeal factories, they prefer to sell their fish to the cage farmers. While there is no closed season for fishing, the country has banned certain types of fishing gear such as trawl nets.

Perspective of fishers. The fishing crew was interviewed on their boat. The boat operated on a commission basis: after deducting the operational expenses, the owner is given 50 percent of the profit and the crew members share the remaining 50 percent. A fishing trip can take up to a week, and in the past, incomes have been good. The fishers were confident that if the farmers switched to a pellet feed, it would not have any effect on their incomes. They said that they could sell the catch to salted fish producers or to the local fishmeal factory. In terms of supplying the fishmeal producers, it is not the price that they pay for the fish but rather the delay in payment that they found annoying. In fact, the fishmeal factories pay more for their fish than the fish farmers but the farmers pay cash on delivery.

Perspectives of two low-value fish suppliers. Mr. Uddin is a low-value fish supplier who supplies several cage farmers. There are several boats operating in the area that primarily target food fish. Bycatch is sold to traders who supply the cage farmers or process the fish themselves as dried salted fish. He collects 400–500 kg of fish per day which he supplies to farmers with whom he has made prior sales agreements. The price is fixed on a monthly basis by the cage owners, and it is the responsibility of the trader to buy the fish and supply at the negotiated price. Under this arrangement, some days the traders will lose money, while at other times they will make a good profit. In a month, he is able to earn a profit of about US\$1 000. This being a fairly substantial income, Mr. Uddin was asked what impact a change from low-value fish to pellet feeds would have on his business. He thought that there would be no problem selling the low-value fish for human consumption or for processing into fishmeal. There appears to be an equal and good demand for food fish and for fishmeal processing. Mr. Uddin's wife assists in managing the money. His parents had only 2 ha of land and five children, and as a result, they urged him to take up a non-agricultural vocation. He found the fish trade a stable and lucrative business.

Forty-four year old Dono Tariono collects an average of 150–200 kg of fish a day and distributes it to cage farmers. He sorts the fish and sells the smaller fish to be used in the grow out systems, and reserves the bigger fish as feed for the brood fish. When he was told of the potential switch to pellet feeds by the grouper farmers, he saw no problem as he could sell his fish to other customers who could process it as salted fish, fish balls, crispy snacks etc. He indicated that he would have no problem to sell his fish, and felt the switch would have no impact on his livelihood. As to whether fish should be fed to as a feed to fish or to people, he thought that Indonesia still has an abundance of fish that is available for people to consume, and he felt that low-value fish could be fed to groupers. His wife also earns money by weaving nets for cages, and by making a substance known as *sambatan* that is spread in the water to attract fish.

3) *Thailand*

In Thailand there are smaller boats that go out fishing every evening and return by morning. They sell the high value fish for human consumption, and the low-value fish

is sold to the cage farmers. If there is no market for the fish, they sell it to the local fishmeal factories. Thus, the fishers thought that there would be no adverse impacts on their livelihoods if the cage farmers started to use pellet feeds.

Perspective of a fish farming family. Mrs. Somrit's family took up cage farming after the 2004 tsunami. Before that, the family was engaged in fishing. The family now has 52 cage units of 3 x 3 x 1.5 m. They raise barramundi, humpback grouper and trevally. The family's main source of income is cage culture. Barramundi culture has been reasonably successful, and to date, they had raised two crops using trash fish/low-value fish. The fish are harvested when they attain a size of 700–800g, usually in seven months. Trevally is grown in a similar fashion to the seabass, and there is good market for this species.

Fishing. The family catches fish and sells the high value fish in the market, and feeds the low-value fish to their cultured fish. Her daughter and son-in law go out fishing everyday and deliver the low-value fish to the farm. In turn, the parents help to maintain her daughter's cages. When they have no fish, they buy low-value fish from the market. These are fish that have already had the meat removed from the carcass. If this is unavailable, they buy whole fish for THB10–12/kg (US\$0.33–0.40).

4) Viet Nam

In Viet Nam, most of the low-value fish that is available is derived from bycatch from commercial fishing boats. The fishers did not think that the adoption of pellet feeds would have a negative impact on their sales. They believe that their low-value fish can be sold to lobster grow-out farmers, fishmeal factories, or makers of fish sauce.

Perspective of a fish supplier. The leader of the low-value fish suppliers' group (an informal association) Mr. Ho Nguyen Minh, aged 50, has been engaged in fishing for more than three decades. Several of the fishers in the area trawl for fish using small boats (15–17 meters) that are powered by 60–70 hp engines. According to Mr. Minh, most people catch low-value fish as a bycatch that depending on the fishing ground, may account for as much as 50 percent of the catch. The bycatch is sold for VND3 000–7 000/kg (US\$0.17–0.39), and the food fish is sold for VND20 000–30 000/kg (US\$1.12–1.68). Although Mr. Minh felt that farmers may decide not to use pellet feeds for all their culture species, he suggested that it was necessary to find alternative feeding strategies to ensure that the low-value fish was optimally utilized. The operational cost of fishing is high, and unless the boat owners are able to sell all their catch, including the low-value fish, it is unlikely that fishing would remain profitable. Each boat has a crew of 8–10 people. Once expenses have been deducted, 50 percent of the profit is allocated to the boat owner, and 50 percent to the crew.

Mr Minh believed that fish grown on low-value fish taste better, and it is for this reason that farmers will continue to use low-value fish as a feed source. He also believed that groupers cannot grow well on pellet feeds, and thus low-value fish will continue to be the feed of choice for these fish.

There is no closed season for fishing in Viet Nam, and farmers can rely on a supply of low-value fish throughout the year. When the fishers were asked whether it would be worthwhile to impose a closed season, similar to the one currently in place in China, they responded that such fishing restrictions could be imposed if alternative livelihoods for the fishers were provided during the closed fishing period.

VIII. Crosscutting issues

The central issue addressed by the project is the continuing use of low-value fish in marine finfish cage farming. Stated as a practical problem, the issue is how the reliance of small-scale farmers on using low-value fish as a feed can be reduced, their profitability improved, and the sector sustained. Associated with this problem statement are a host of issues that are in essence biological, technical, economic, and social-cultural.

1. FUNDAMENTAL ISSUES

Biological-technical issues:

- 1) improving biological (and economic) FCRs – this would reduce use of feed, increase yield and profitability, and address environmental impact issues arising from excess feeding;
- 2) mitigation of environmental pollution – promotes good health, improves growth and yields, prevents the exceeding of a site's carrying capacity;
- 3) control of diseases and parasites – reduces cost of production, assures improved yields;
- 4) mitigation of natural, biological and economic risks – reduces risks to crops and farm infrastructure, assures the security of investments, improves profitability prospects;
- 5) access to land and water resources, production inputs and product markets – encourages investments in farm improvements and better practices, assures security of investment; and
- 6) reducing the reliance on wild caught seed.

Economic issues:

- 1) increasing yields and product value – higher returns, farmers capturing more value from farm products;
- 2) reducing operating cost and losses – higher returns;
- 3) increasing farm gate prices – higher returns;
- 4) shortening the market chain – less transport costs, higher returns; and
- 5) increasing the technical capacity of labour – improves labour productivity.

Social issues:

- 1) access to livelihood capitals – greater ability to invest and carry out livelihood activities, earn income, strengthens the resilience to natural and economic shocks;
- 2) livelihood strategies – improved capacity to exploit livelihood opportunities and address livelihood threats;
- 3) livelihood opportunities – diversified options and sufficient livelihood assets to support diversification;
- 4) mitigation of social risks – avoids challenges to the farm and farm practices (reduction of social and environmental impacts; social responsibility); and
- 5) household welfare and security – improved human capital, better capacity for productive work.

Cultural issues:

- 1) taste of fish as a result of feed type – better farming, harvesting and post-harvest techniques; and
- 2) preferences and perceptions of consumers – improved marketing strategies.

2. CROSSCUTTING ISSUES

All the above issues are inter-related and their relationships and linkages give rise to a set of second-tier issues that are characterized by their broader impacts on the resolution of the problems. These are crosscutting issues, and they can be categorized into capacity building, institutional, and policy issues.

- 1) Capacity building issues:
 - need for better management practices;
 - training of farmers and extension workers; and
 - institutional strengthening.
- 2) Institutional issues:
 - technology development, dissemination and utilisation systems;
 - farmers organizations;
 - public-private partnerships; and
 - regional cooperation.
- 3) Policy issues:
 - integrated coastal zone management;
 - zoning and development planning for marine cage culture;
 - incentives, green subsidies, the provision of technical assistance to fishers;
 - market incentives and the creation of demand for processed low-value fish as food;
 - management of fishery resources including closed seasons, fishing capacity, gears; and
 - guidelines for offshore aquaculture – as a related issue to reducing fishing capacity, policy interventions should consider the employment opportunities for displaced fishers in an industrial scale offshore mariculture.

While this list of crosscutting issues is not comprehensive, it generally reflects the recommendations of the FAO Expert Workshop held in 2007 in Kochi, India on the Use of Wild Fish and/or Other Aquatic Species as Feed in Aquaculture and its Implications to Food Security and Poverty Alleviation (FAO, 2008).

3. PRIORITIES

Taking these crosscutting issues into consideration, the priority areas that the stakeholders recommended for urgent attention are:

1. Regional cooperation in the development and dissemination of BMPs. Management practices vary widely with corresponding differences in farm performance. The need for better management practices for marine cage culture was universally agreed upon by the stakeholders that were involved in the case studies. The development of a subsector-based BMP for cage mariculture was recommended by the FAO/NACA Regional Workshop on the Future of Mariculture (Lovatelli *et al.*, 2008).
2. Development of Public-private-partnerships to resolve R&D issues. The absence of species specific pellet formulations is a common problem. Although some marine finfish diets are available, they are not designed for the culture species (e.g. groupers) that are becoming increasingly popular as a result of their high market price and profitability. The current low production volumes of some of these culture species suggest that there is little economic incentive for manufacturers to produce species-specific formulations.
3. Policy and regulations. The lack of marine cage culture site selection, zoning and integrated coastal zone management policy and regulations are the issues in China and Indonesia. In these countries, the local conditions at the case study sites

suffered from overcrowding, conflicts with other resource users and problems with water quality, disease and fish mortalities. Sites where the carrying capacities have been exceeded have resulted in disease and mortality problems in Viet Nam lobster cage culture operations. In Thailand where the case study areas had lower production level, there appeared to be few problems associated with carrying capacity. The estuarine sites however are vulnerable to freshwater influx that can kill the stock. Culturing fish in estuaries also limits the species that can be cultured to those that are euryhaline or can tolerate lower salinities - this precludes many of the higher value species such as coral trout grouper (*Plectropomus leopardus*). The selection of new sites that are suitable for aquaculture, zoning, and the improved management planning of current and new sites would help to avoid user conflicts, overcrowding and prevent the farmers from exceeding the carrying capacities of the water bodies.

4. Institutional development and capacity building. Farmers' associations in the trial countries were uncommon, and where present, they were not being utilized to the full benefit of the club members. Farmers' clubs are encouraged by the Government in China. In Indonesia, the respondent farmers are members of an association, but it was not being utilized to its full potential - it served mostly as a forum among the farmers, and it was not being used as an instrument to improve their economies of scale, and gain better bargaining power and other benefits. Aquaclubs were not present in Thailand, and have only recently been organized in Viet Nam. The farmers were encouraged by the project team to organize themselves into farmer associations.
5. Wider dissemination of the project results will clearly increase the benefits from the study. In this respect, communication with a range of stakeholders internationally and locally, and particularly with farmers, is beneficial. A number of dissemination activities have been tried at the project scale; these and other means need to be scaled up. Scaling up these activities will also present opportunities for cooperation between the government, the private sector and the farmer associations.
6. As low-value fish is likely to remain the predominant feed source for farmed marine fish for another ten years or so, a better understanding of the dynamics of its use, quality, and price, and its role in fishers' livelihoods is required. This information would inform strategies to ease the industry's transition to pellet feed without disrupting the livelihoods of fishers and fish suppliers.
7. Marketing issues were identified by the farmers in Indonesia, and with the exception of China, are likely to be common to the other trial countries. Indonesian farmers had a minimal understanding of the market chain, and it was observed that there was a large discrepancy in prices paid at the farm gate and wholesale prices in Singapore and China, Hong Kong SAR. A number of measures were identified that could help to resolve this issue. These included providing real time information on fish prices in the destination markets, group marketing and shortening of the market chain by reducing the reliance on middlemen.
8. The need for Government policies that are favourable to marine cage farming was raised as an issue in China. This is also an issue in the other trial countries.

Harvest of brown-marbled grouper after completion of farmers' participatory cage trial, Lampung Bay, Bandar Lampung, Indonesia.

Courtesy of FAO/M.C. Nandeeshha



Humpback grouper juveniles (2 months old, 5–6 cm length) in MCMD (Main Centre for Mariculture Development), Bandar Lampung, Indonesia.

Courtesy of FAO/Mohammad Hasan

IX. Conclusions and recommendations

The conclusions were drawn from the different components and from the final stakeholders' workshop.

A. CONCLUSIONS

1. Farmers' participatory trials and stakeholders' workshops

- Pellet feeds offer a viable alternative to low-value fish as a feed for marine finfish cage culture. The farm trials generally demonstrated the technical feasibility of using pellet feeds to replace low-value fish in marine finfish cage culture.
- Feeding pellet feeds and low-value fish resulted in similar performances in terms of growth, survival, food conversion, production and the economics of the culture operation. The results varied between countries; however this was due to variations in farm management practices and the prices and quality of the low-value fish and pellet feeds.
- Price and quality fluctuations may influence the cost effectiveness of the feed types. However, there is little information available pertaining to the important quality and economic attributes of low-value fish and its uses. These are needed as low-value fish is likely to remain a major protein source for cultured marine fish for the next 10 years or so. At present, the use of pellet feeds appears to have no advantage over feeding low-value fish except in times of low availability of low-value fish. The exception is China where low-value fish is of a low quality but remains relatively expensive.
- In general, the pellet feeds used in the farm trials were non-species specific and were of varying quality. Feed analyses showed that pellet feeds were generally acceptable for fish culture in terms of their crude protein, lipid, and moisture contents. The ash content of some of the diets used in the trial in China appeared to be near levels that are detrimental to growth. High ash fishmeal diets can result in zinc deficiencies in cultured fish.
- The use of pellet feeds in cage culture was new to some of the trial farmers. Inexperience in managing the pellet feeds would have reduced their efficacy in the trials.
- Management practices varied widely between the farmers within each country and between countries. The growth and feed utilization parameters that were measured followed a similar pattern to that of the management variability. In this respect, the greatest potential for improvements in growth, feed utilization, farm profitability, and reducing environmental impacts are likely to come from better management practices.
- There were clear indications that some of the traditional perceptions, particularly in relation to the difficulties in weaning wild caught seed onto pellet feeds, and changing from one feed type to the other were not true. The results of the farmer trials have generally changed the farmers' perception that pellet feeds lead to poor growth and lower fish flesh quality. It has been reported that in China, more farmers were moving away from using low-value fish as a feed source.
- There were a range of credit schemes available to farmers. One possible reason for the reluctance of banks to lend to the subsector is the high risks associated with marine cage culture. A microcredit scheme would improve farmers' ability to take

up better management practices, possibly facilitate a switch to pellet feeds, and remove their dependence on low-value fish traders.

- The high risks associated with marine cage fish culture makes the small-scale farmers economically vulnerable. Crop insurance is not available. This is because there is no commercial insurance for cage culture, and for aquaculture in general in the region except in China.
- Existing farmer clubs were not being utilized to their full potential. In this respect, and with the assistance of the local fisheries department, farmers that were in areas that did not have aquaclubs were encouraged to form associations. Those places that already have aquaclubs were encouraged to better utilize them to achieve the benefits that such association can bring, for example, bulk order discounts for feed, and the joint marketing of products.
- Organizing small scale farmers is a way to increase leverage and generate economies of scale. The organization of small scale farmers into clubs or associations, with legal support as in the case of Indian shrimp farmers, would be a way forward. The government of the participating countries have taken steps to promote the organization of small-scale farmers to strengthen their bargaining power with input suppliers and product buyers. It also facilitates the adoption of better practices and the provision of extension services. The project has shown that it is possible to achieve a step-wise recognition of organized farmer groups by government authorities, technical institutions, and commercial input providers that leads to the provision of credit, crop insurance, cluster development, certification, production, marketing and other support services.
- A poor understanding of the value chain and the lack of access to market information has resulted in farmers receiving low market prices from their fish. This could also be addressed by organizing the farmers into clubs or associations and assisting them with their production and marketing.
- The involvement of fish farmers, farmer organizations, low-value fish suppliers, and feed companies should be encouraged in projects of this nature. In this study, this approach has ensured that the results obtained were relevant to industry in the real world, and assisted in the dissemination of results to farmers and other key stakeholders.

2. Environmental impact study

- The results confirmed that feeding with either feed type does not have as much local impact on water and sediment quality as the intensity of feeding.
- One of the greatest influences on the amount of excess nutrients entering the environment is overfeeding, which is the result of poor feeding strategies. The FCRs can be improved by providing the correct feed amount, and optimizing feed duration, frequency and timing. The case of the woman cage culture farmer in Thailand who worked out a feeding protocol that greatly improved her FCRs is illustrative of this lesson.
- The quality of the low-value fish can be a disease risk factor. The highest bacterial loadings were derived from feeding low-value fish that had been stored on ice before feeding. In addition, there was an increase in bacterial release to the culture waters that was associated with the length of storage of the low-value fish on ice.
- The estimated energy cost of producing one kilogramme of farmed fish was significantly lower when using low-value fish than pellet feeds when trash fish/low-value fish were harvested using small boats in artisanal fishing. This was due to the fact that the embodied energy in the pellet feed is much higher than it is in the low-value fish. While this cannot be used as an argument to favour the use of low-value fish, it is a useful consideration in terms of farm level feed use efficiency.

- The fish-in fish-out ratios provide estimates of the amount of fish that is needed to produce one kilogramme of farmed fish. These ratios showed that as much as three times more fish is needed to produce one kilogramme of fish when low-value fish as opposed to pellet feeds is used. As an input-output measure, it is less useful as an economic argument to farmers for using pellet feeds than FCR or feed cost of production.

3. Livelihood analysis of fishers

- The threat to fishers' livelihoods from the transition by farmers to pellet feeds has varying consequences in terms of income earned from the fish and the availability of other livelihood options. There would still be a market for the low-value fish.
- The livelihood capitals available that would enable them to cope with threats to their fishery-based livelihoods are adequate for the Thai, Indonesian and Vietnamese fishers. This is due to the availability of land for crop cultivation, the availability of a mix of informal and formal sources of credit, and the general adequacy of family labour for cage culture as well as for fishing. Chinese fishers enjoy subsidies for fuel and soon they will have a government sponsored pension plan. In the long term, the subsidy may however work against the sustainability of their livelihoods as it maintains the already high fishing pressure on an already depleted fishery resource. In the future, it will not be the lack of a market, but rather the lack of fish to catch that will compel them to exit the fishing sector.
- The traders in low-value fish perform an important service by providing fish conveniently and on favourable terms to the farmers. This strong social relation could make farmers' transition to commercial pellet feed slow. An institutional credit scheme that farmers can easily access could free them of their dependence on the low-value fish traders.

B. RECOMMENDATIONS

This section largely draws from the recommendations formulated by the stakeholders' workshop held at the end of project. The report of the workshop is presented in Annex 4.

1. Pellet feed for mariculture

Marine cage culture in many of the Asian countries is still dependent on low-value fish. The sustainability of the low-value fishery resources and the negative impacts on the environment that are associated with its use as feed favour the use of pellet feeds. In addition, the intensive research and development that has been undertaken on feeds that use plant based (mostly soybean) alternative to fishmeal – while geared mostly to species other than those commonly grown in the region – will likely yield results that the R&D institutions in the Asia-Pacific region can build upon to develop specific feeds for groupers that would also contain less fishmeal. A broad implication for this prospect would be that the expansion of the finfish mariculture industry in the region shall, with the rest of the world, as well as the crustacean culture industry, reduce the amount of fishmeal in aquafeed (Nordahl, 2011).

Regionally, various finfish species are being farmed. Primarily, these include a number of grouper species (*Epinephelus*, *Cromileptes* and *Plectropomus* spp.), snapper (*Lutjanus* spp.), Asian seabass/barramundi (*Lates calcarifer*), snubnose pompano (*Trachinotus blochii*), cobia, and others. Of these, only the nutrient requirements of the barramundi are well understood. This, and the relatively high volume of barramundi production - when compared to any single species of grouper - has encouraged feed manufacturers to develop and market pellet feeds specifically for barramundi culture. In contrast, the nutrient requirements of the cultured grouper species and the other marine finfish are not well understood. As such, the pellet feeds that are available

for these species are ‘generalized’, and there is uncertainty as to whether these feeds optimize performance. This uncertainty has tended to make farmers less inclined to use the pellet feeds that are currently available in the market. In contrast, and with the exception of the barramundi, the current low volume of production of any one species, does not present an attractive commercial activity for feed manufacturers to produce and market a specific diet for each of the species.

The workshop recognized the need to develop species-specific diets for marine finfish species, defining the nutritional quality, type of ingredients and formulation. The workshop therefore recommended that the public and private sectors be encouraged to study the nutritional requirements of important cultured marine finfish species under different environmental conditions, and that private feed manufacturers should be encouraged to develop appropriate pellet feeds for marine species and make them easily available and affordable to the small-scale farmers.

2. Trash fish/low-value fish

In the foreseeable future, trash fish/low-value fish is likely to continue to be used in most countries in the region as a feed for cultured marine finfish. Currently, farmers either feed trash fish/low-value fish in isolation, or use it in combination with pellet feeds. However, the farmers are beginning to be concerned about the growing scarcity of supply and the increasing prices of trash fish/low-value fish. At present, prices are still low (in most countries), and local supplies are still available. Furthermore, as the purchase of pellet feeds requires large up-front cash payments, the farmers usually find it easier to afford trash fish/low value fish which is purchased on a daily basis. Many farmers also fish and either target low-value species or have access to bycatch to supply their trash fish/low-value fish needs. Other factors that affect their use of pellet feeds include the unavailability of pellet feeds that are designed for the target species, their irregularity of supply, and the relatively high price of these feeds in remote and relatively inaccessible areas.

The consensus was that low-value fish will continue to be used in marine finfish culture in most countries, albeit to varying degrees, and well into the foreseeable future. On the other hand, there is very limited knowledge of its seasonal availability, particularly the seasonality of the dominant species, quality changes, price changes along the value chain, and its other attributes as a commodity. Equally, there is no knowledge pertaining to the parasite loads, and the impact that these parasites may have on the health of the cultured stock. There is also little knowledge pertaining to the origins of the trash fish/low-value fish, such as whether it is derived from artisanal coastal fisheries, fisheries designed for this purpose only, or industrial fisheries.

It was recommended that further studies be undertaken on trash-fish/low-value fish to determine the quantities used, the quality of the product, and its impact on the environment.

3. Better management practices (BMP)

The workshop recognized the urgent need to develop better management practice guides in cage culture of different marine cage cultured species. It recognised that some of the findings of the project on feed types and management can be incorporated into the BMPs. The BMPs could also be modified into specific technical guidelines for marine cage finfish farming in accordance with the FAO Code of Conduct for Responsible Fisheries and Aquaculture (FAO, 1995).

A specific technical recommendation was that the BMPs to be developed should emphasize the resource, economic and environmental impacts of using both types of feed, and the different feed management practices required in small scale marine cage culture; this would guide the development of suitable strategies and protocols for feed management.

The workshop recognized the lack of technical guidelines for good feed management practices for small-scale farmers, and recommended that technical manuals outlining better feed management practices at the farm level should be developed and disseminated to the farmers. These would supplement the BMPs for the entire culture cycle of the important marine finfish species.

The workshop recommended the formation or strengthening of farmer clusters, clubs or associations to facilitate the adoption of BMPs, and to generate the economies of scale that would assist the small farmers in terms of bulk purchasing and the leverage of resources.

4. Dissemination of findings

The workshop agreed that the project has generated information that will be useful to the marine cage finfish farming industry. It noted that the private sector (Thailand) had taken the initiative to support the production and dissemination of the extension materials prepared by NACA. The information from the growth trials, environmental study, farmers' perception and livelihood analyses, could be disseminated through semi-technical magazines such as *Aquaculture Asia* and *FAO Aquaculture Newsletter*, which have a wide readership and, in a way, specialized audiences. The results that are technically robust and can withstand rigorous statistical analyses can be disseminated through peer reviewed processes.

The workshop recommended that the findings of the project should be disseminated as widely as possible to the farmers and other stakeholders. This would include the FAO terminal report/technical paper covering the project findings, NACA publications, country project reports in local languages, extension materials and BMPs for farmers translated into local languages, and through scientific journals. FAO shall be acknowledged in all the materials published. Its participation in the preparation of scientific and related publications is encouraged.

5. Policy

The indications are strong that marine finfish cage culture will continue to expand. An orderly expansion will be facilitated by the following: (a) zoning; (b) the development of an integrated coastal management plan for the existing and potential sites; and (c) the identification of new areas for the industry to develop. The latter will likely entail moving from inner bay to the offshore areas. A move offshore will avoid the negative environmental impact and conflicts with other resource users that are associated with the near shore areas. The workshop recommended the development and implementation of ICZM and the development of policy and technical guidelines for offshore mariculture.

6. Farmer organizations

Currently, there are many small-scale farmer groups operating as clusters and organized as clubs. This should be encouraged and promoted further using the models developed in India and Viet Nam. These models use the step by step approach to the formation of the clubs, and result in improved access to technical and financial services, marketing, and the promotion of good governance.

7. Increased capacity for quality seed production in Viet Nam and Thailand

The follow-up mission confirmed that access to quality seed is an issue that is constraining sector development in Viet Nam and Thailand. It was recommended that Viet Nam adopt the Indonesian model of seed production. For Thailand, the recommendation is to improve the capacities of government and private hatcheries, and explore the possibility of some farmers nursing fry to juveniles, and selling the juveniles to the grow-out farmers.

*Farmer feeding minced trash fish to his stock,
Lampung Bay, Bandar Lampung, Indonesia.
Courtesy of FAO/Mohammad Hasan*



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