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Cover photographs:
Left: Low-value fish harvested from Lampung Bay, Bandar Lampung, Indonesia (courtesy of FAO/Patrick White).
Right top to bottom: Preparing trash fish for marine cage fishes, Zhanjiang, Guangdong, China (courtesy of FAO/M.C. Nandeesha). Compound pellet feed for marine cage culture in Thailand (courtesy of FAO/Mohammad Hasan).

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This fisheries and aquaculture technical paper presents the results of the FAO Regional Technical Cooperation Project "Reducing the dependence on the utilization of trash fish/low-value fish as feed for aquaculture of marine finfish in the Asian Region (TCP/RAS/320 (D)", which was implemented between August 2008 and July 2011 in four selected countries in Asia; China, Indonesia, Thailand and Viet Nam. The project has been implemented in collaboration with the FAO Regional Office for Asia-Pacific (FAORAP) and the Network of Aquaculture Centres in Asia and the Pacific (NACA) and was coordinated by Mohammad R. Hasan, Aquaculture Officer (FIRA). This document comprises two sections; Part A being the consolidated report and a synthesis of the results of the different components and activities of the project, and Part B being the annexes containing the detailed reports of the above mentioned components. The preparation of this technical paper was also coordinated by Mohammad R. Hasan and many persons contributed both technically and/or editorially to the production of this volume.

Abstract

This technical paper presents the findings of the FAO Regional Technical Cooperation Project TCP/RAS/3203 (D) "Reducing the dependence on the utilization of trash fish/low-value fish as feed for aquaculture of marine finfish in the Asian Region," which was implemented between 1 August 2008 and 31 July 2011 in China, Indonesia, Thailand and Viet Nam. It comprises the results of the project components, namely, farmers' participatory on-farm trials and a concurrent survey of farmers' perceptions concerning the use of two feed types and microcredit, environmental impact assessments of the use of both feed types, and a survey and analysis of the potential impacts of a change to pellet feeds on the livelihood prospects of fishers and suppliers of trash fish/low-value fish. An assessment of changes in the perceptions of farmers before and after the farm trials was undertaken, and a final regional stakeholders' workshop was conducted after the completion of all the project components. Incorporated in the relevant parts of the report are the findings of a follow-up mission conducted 16 months after the end of the project. This mission was designed to confirm the findings, and assess further activities in line with the recommendations made at the final regional stakeholders' workshop.

There were indications of the clear benefits to farmers as well as to the environment of adopting pellet feeds. Some indicators were not statistically significant, but present opportunities for addressing the constraints to the farmers' adoption of pellet feeds. A dominant finding was that the technical and economic performance from pellet feeds can be considerably enhanced by improving feed management, which was not a common attribute among the trial farmers. Furthermore, overall farm performance, whichever feed type was used, could be improved by introducing better management practices. The environmental impact assessments on the use of the two feed types suggested that good feed management and overall farming practices, and improving the quality of trash fish/low-value fish or pellets reduce the impacts of feed on the water beneath and around the culture sites. In addition, a good culture site where the carrying capacity is not stressed by aquaculture and non-aquaculture activities will considerably reduce the mortality risks from biotic and abiotic hazards. The technical and economic findings of the study were noted by the farmers, and contributed to the changes in their attitudes towards the pellet feeds from negative or neutral to positive. The recommendations of the project included providing the opportunities and enabling the farmers to translate their positive attitude into actual and sustained adoption of pellet feeds. Interventions that would promote the adoption of pellet feeds, among others, would include reasonable credit facility, species- and growth-stage-specific feed formulations, farmers being associated to take advantage of economy of scale, and advice on better management practices. A standardized guide for a better management practice in cage mariculture was unanimously requested by the farmers.

The impact on the livelihood of fishers and fish suppliers from losing the cage culture industry as a direct market for their trash fish/low-value fish was found to be minimal; they have robust coping mechanisms, which can be strengthened by policy and technical assistance from government.

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Contents

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Abbreviations and acronyms

AA	amino acid
ACIAR	Australian Centre for International Agriculture Research
AOAC	Association of Analytical Communities (previously Association of Official Analytical Chemists; previously Association of Official Agricultural Chemists)
BMP	better management practice
CF	condition factor
cfu	colony forming unit
CNY	Chinese Yuan Renminbi
DO	dissolved oxygen
EEZs	exclusive economic zones
eFCR	economic feed conversion ratio
FAO	Food and Agriculture Organization of the United Nations
FAO RAP	Regional Office for Asia and the Pacific of FAO
FCR	feed conversion ratio
FIEP	Fisheries Economics and Policy Division of the FAO Fisheries and Aquaculture Department
FIFO	fish-in fish-out
FIRA	Aquaculture Service of the FAO Fisheries and Aquaculture Department
GIS	geographical information system
ICZM	integrated coastal zone management
IDR	Indonesian Rupiah
LRFFT	live reef food fish trade
LFFRT	live food fish restaurant trade
NACA	Network of Aquaculture Centres in Asia-Pacific
NGOs	non-governmental organizations
NH_3	ammonia
NO_2	nitrite
NO_3	nitrate
Pf	pellet feed
pH	potential hydrogen ion concentration
PO_4	phosphate
PPP	public private partnership
R&D	Research & Development
SGR	specific growth rate
Tf/Lvf	trash fish/low-value fish
TCP	Technical Cooperation Programme
THB	Thai Baht
TNC	the Nature Conservancy
TOM	total organic matter
US$	US dollar
VND	Vietnamese Dong
VNN	viral nervous necrosis

Part A – Consolidated report and synthesis of the project findings[1]

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 FIFO).
- 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 competiveness 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 famers' 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 fish[1]. 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,

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[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/M.C. Nandeesha

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 erythopterus*) 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	· Comparative technical and economic efficiencies · Farmers' feed management practices · Quantitative and qualitative variabilities associated with efficiencies	· Critical factors of efficiency and profitability - Practices - Quality of feed - Specificity of feed to species and size - Reliability and quality of seed supply	· 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	· BMPs · Technical manuals · Farmers associations · Capacity building programme · R&D programme
Survey of farmer perceptions on feed type and credit	· Technical basis of perceptions · Technical and social-cultural constraints to the adoption of pellet feeds	· Economic , social and cultural basis for changes in perceptions · Attitude towards microcredit	· Communication, extension strategy · Access to credit	· Extension materials · Advisory on credit provision · Crop insurance schemes (market and public)
Environment Study	· Risk factors from - feed type - feed quality - feeding practice · Impacts of feed type on culture site · Energy use by feed type · Fish resource use by feed type	· Feed quality control · Feeding practice · Farm management · Farm siting	· Arguments for zoning, site selection, carrying capacity study, regulations	· BMPs · Technical guides for site selection · Guides for licensing and area management
Livelihood analysis of fish suppliers	· Characterization of threats to traditional livelihoods · Assessment of livelihood assets, strategies, and options	· Adaptation strategy · Alternative livelihood opportunities	· Fishery resource management	· 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, NH_3), 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 fish[2] 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	<u>Some concurrence from the project.</u> 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. 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.
2. Convenient supply of fish particularly during certain seasons	<u>Most of the time, trash fish/low-value fish is readily available and pellet feeds are not.</u> 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.
3. Low-value fish is still relatively cheap for aquaculture	Prices for trash fish/low-value are increasing as are the ingredients for pellet feeds 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. 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.

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)	Project finding concurs with this, but the convenience and time savings from using pellet feeds might offset this factor. 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. 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.
Factors that will drive aquaculture away from the use of low-value fish	**Project findings that relate to the 2005 workshop conclusions**
a. Profitability	Not clear from the results; there are many factors other than feed type. 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. 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. The comparative results: 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.
1. Increase in the price of trash fish/low-value fish	Study finding in Viet Nam concurs with statement. 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.
2. Increased competition for alternative uses (such as for direct human consumption)	No evidence was derived from the project; it was not within the scope of the project. 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. 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.
3. Scaling up of aquaculture units: would require pellet feeds	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. 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. 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. 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.

TABLE 2 (CONTINUED)

Drivers of the use of low-value fish in aquaculture	**Project findings that address the 2005 workshop conclusions**
4. Disease outbreaks	Not supported by evidence, but the disease risk is higher when using low-value fish. 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.
b. Efficiency of operation	
1. General unavailability, seasonality or uncertainty in the supply of low-value fish	Not a critical factor with the low stocking densities and low volumes of production. 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.
2. Pellet feed readily available at reasonable prices	The project finding supports this position. 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.
3. Information, knowledge, education and demonstration of the value of pellet feed	High priority. 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. 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. Demonstration projects and farmer-to-farmer learning activities were suggested.
4. Increasing knowledge about the inefficiency of poor quality of low-value fish (farm economics, water quality, and wider environmental pollution)	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. Regardless of feed type, it is the farm practices and natural conditions of the sites that caused the variations in performance. 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.
5. Overcome taste issues from the use of pellet feeds	The project confirmed this prevailing farmers' perception. 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. The farmer trials have generally changed the farmers' perception that pellet feeds leads to poor growth and lower fish flesh quality. More farmers are moving away from low-value fish to pellet feeds in China.
6. Increased availability of cost-efficient substitutes (plant proteins, terrestrial animal meals, fish processing by-products)	Not within the scope of the project. 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. 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.

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	Supportive of this but not solely in terms of legislation. 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. There were no apparent differences in impacts measured in terms of dissolved nutrients (N and P, NH_3), and dissolved oxygen at the sites. This was attributed to the low stocking densities used in the farm trials.
2. Legislation or policy to prevent targeted catch	Not within the scope of project. 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. A suggestion from the final regional stakeholders' workshop was to study the origins, catch volumes, and species composition of low-value fish catches.
3. Pressure from consumers for sustainably produced aquatic products	Not within the scope of the project. 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.
4. Requirement for feed ingredient traceability to allow for the export of the product	Not within the scope of project. See preceding issue.

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 FINDINGS[3]

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 erythopterus*), 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 coralgrouper 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 (IDR[4] 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 Noctilluca sp, Thallasiosira 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.

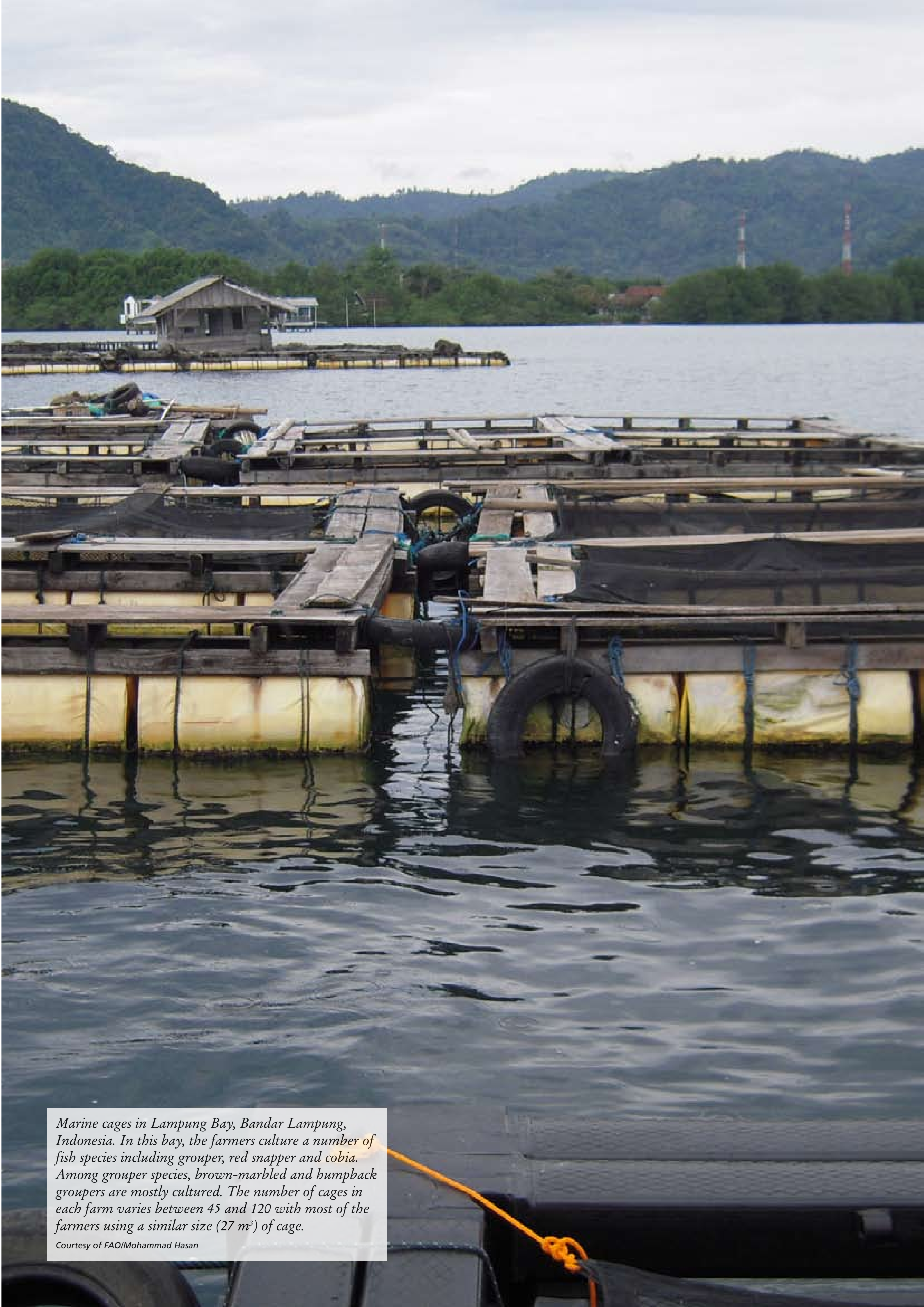
Disease. Disease events occurred three times. At the beginning of the project (April–June 2009)), the middle (October–November 2009) and towards the end of the project (January–February 2010). At the beginning of the project, a disease outbreak occurred resulting in a very high fish mortality rate. During 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 m^3) 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, Khlong 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 m^3.

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 Lumpung 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 famers 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 famers 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 FINDINGS[5]

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, NH_3), 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

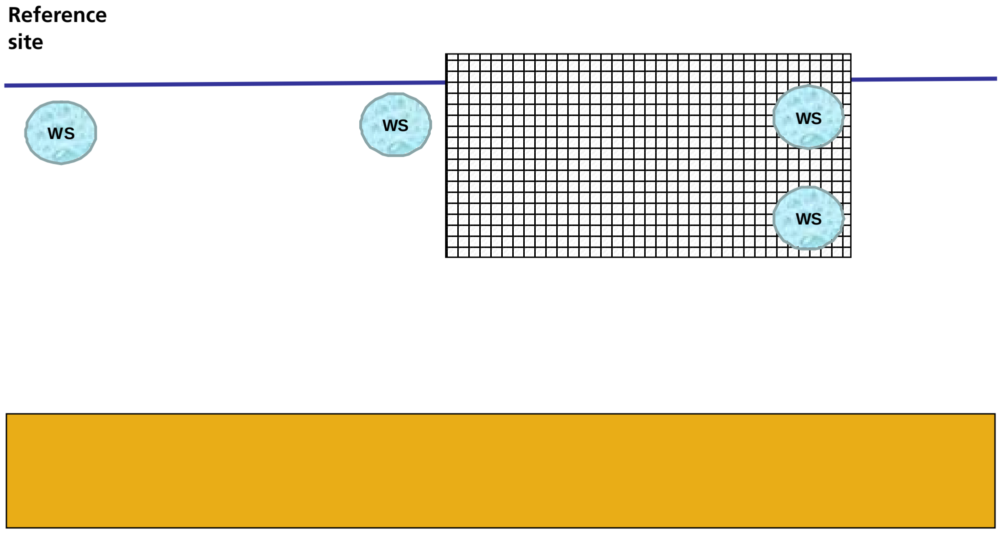
The findings from each parameter are summarised below. Detailed descriptions of these findings are presented in Annex 2.

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

FIGURE 1
Water quality sample locations



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 m^3 were stocked at a density of 2.6 kg/m^3. This gave a stocking density of 7.7 kg/m^2.

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/m^3. This would give a stocking density of 30 to 45 kg/m^2 (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 (NH_3-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 (NO_2-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 (NO_3-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 (PO_4-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:

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

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. Nandeesha

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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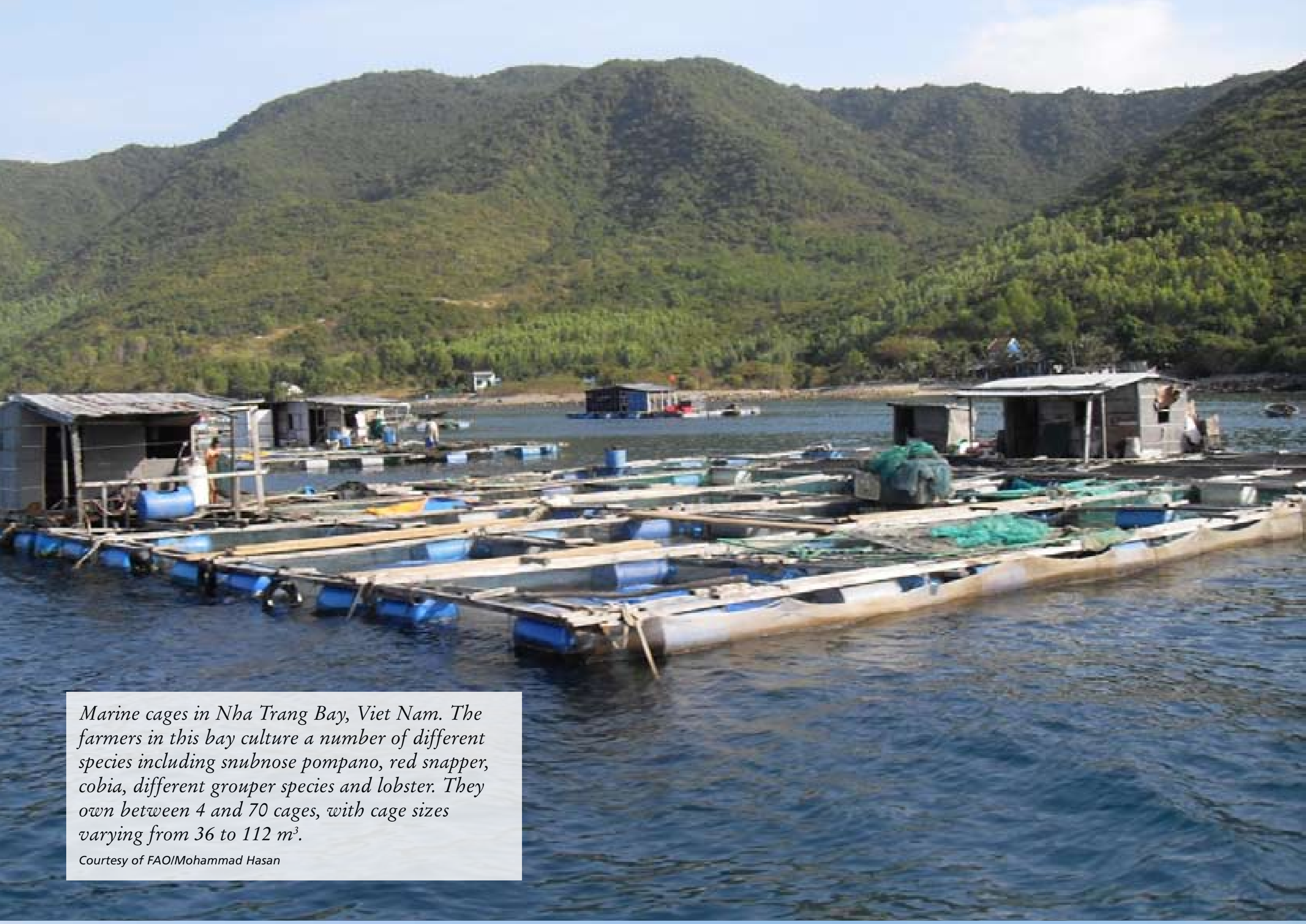
Part B – Annexes

1. FARMERS' PARTICIPATORY TRIALS
2. COMPARISON OF THE ENVIRONMENTAL IMPACT BETWEEN FISH FED TRASH FISH/LOW-VALUE FISH AND PELLET
3. IMPACTS OF PELLET FEED USE IN MARINE CAGE CULTURE ON THE SECTOR AND LIVELIHOODS
4. REPORT OF THE FINAL REGIONAL STAKEHOLDERS' WORKSHOP
5. PROJECT UPTAKE AND FUTURE PRIORITIES



Marine cages in Nha Trang Bay, Viet Nam. The farmers in this bay culture a number of different species including snubnose pompano, red snapper, cobia, different grouper species and lobster. They own between 4 and 70 cages, with cage sizes varying from 36 to 112 m³.
Courtesy of FAO/Mohammad Hasan

Small-scale marine finfish cages in Krabi estuary, Khlong Prasong district, Thailand. Cage sizes in this area are generally small varying between 10 and 18 m³.
Courtesy of FAO/Mohammad Hasan

ANNEX 1

Farmers' participatory trials[1]

EXECUTIVE SUMMARY

Farm based trials culturing finfish (barramundi, orange-spotted/green grouper, red snapper, snubnose pompano and brown-marbled/tiger grouper) in marine or brackish water cages were undertaken in China, Indonesia, Thailand and Viet Nam. The trials were undertaken on farms under commercial conditions and compared the growth and feed utilization efficiency of fish fed trash fish/low-value fish and those fed commercial pellet feeds. The commercial pellet feeds used in the trials were analysed for their proximate and amino acid compositions. Water quality parameters and the health status of the fish were also monitored during the trials.

Orange-spotted grouper and red snapper were cultured in the trial in China. It was observed that by the end of the trial, the orange-spotted grouper fed the pellets were significantly larger than those fed the trash fish/low-value fish. However, there was no significant difference in the growth of the red snapper fed either diet. The FCRs were much lower when the fish were fed the pellets, as was the feed cost of production (cost/kg fish produced). At times, the water quality was poor and impacted on fish health and survival. However, feed type did not significantly affect fish survival or water quality.

Brown-marbled grouper was cultured in the trial in Indonesia. It was observed that by the end of the trial, the brown-marbled grouper fed the pellets were smaller than those fed the trash fish/low-value fish, but the differences were not statistically significant. The FCRs were significantly lower for the fish fed the pellets. However, due to the differences in feed costs, the feed cost of production (cost/kg fish produced) was similar for both feed types. Water quality was not always optimal during the trials. Phytoplankton blooms occurred during the initial stages of the trials, these included toxic species that impacted on fish survival.

Barramundi and brown-marbled grouper were cultured in the trial in Thailand. It was observed that feed type did not significantly affect the specific growth rates of the barramundi. However, at one farm, the final mean fish weights were significantly different between the fish fed the different feed types. The FCRs were generally higher in those groups that were fed the trash fish/low-value fish. Large variations in growth and feed utilization performance of the barramundi were observed across the farms. Compared to barramundi that were fed the pellet feeds, the feed cost of production was much lower for the barramundi fed the trash fish/low-value fish. No consistent trend in the growth performance of the brown-marbled grouper fed the two dietary treatments could be established, and the growth performance of the fish fed the trash fish/low-value fish was sometimes significantly higher than that of the fish fed the pellet feeds. A similar trend was observed with the FCRs of brown-marbled grouper. The feed cost of production was slightly higher for brown-marbled grouper fed the trash fish/low-value fish as compared to the pellet feeds. The water quality parameters monitored during the trial were all within a suitable range for barramundi and brown-marbled grouper culture. Water temperature was not recorded during the trials, however it was noted that at times, it decreased rapidly to 22°C at some farm sites. This resulted in mortalities. The data for these farms was excluded from the analyses. The use of either the trash fish/low-value fish or the pellet feeds did not significantly affect the water quality at the farms.

[1] This annex has been prepared by Dr Nigel Abery, FAO Consultant to the project.

Snubnose pompano and red snapper, were cultured in the trial in Viet Nam. Across all the farms, the fish that were fed pellet feeds grew to a higher final mean weight than those fed the trash fish/low-value fish. This difference in growth response was significant in six of the ten farms that cultured snubnose pompano, and in one farm that cultured red snapper. At the farm level, the remaining growth and feed utilization parameters were not analysed statistically. This was due to the low number of replicates (one replicate per treatment per farm), and the concomitant limited analytical power of the statistics. The fish that were fed the trash fish/low-value fish recorded FCRs that were between 3 and 7 times higher (mean: 4.5) than those fed the pellet feeds. Survival rates were found to be slightly higher in those groups that were fed the pellet feeds.

Throughout all of the trials, and across the different farms and countries, it was observed that there was a high degree of variation in the performance of the cultured fish. Though some of these differences might be attributed to the local conditions (turbidity, water currents etc.), it was concluded that improvements in feed management practices regardless of feed type are likely to improve feed utilization, environmental sustainability, and farm profitability.

1. INTRODUCTION

Farmer trials were undertaken in each of the countries that participated in the programme. While a common methodology was applied across all the trial sites and countries, the inherent variability between countries, notably seed supply issues, necessitated some minor variance in the methodologies applied. The common methodology that was applied across the case study sites is presented in Section 2.

1.1 Objective

The objective of the farmer trials was to assess and compare the feed utilization, feed cost performance, and growth of marine finfish cultured in cages, and fed either trash fish/low-value fish or pellet feeds.

2. GENERAL METHODOLOGY

The farmer trials were undertaken in China, Indonesia, Thailand and Viet Nam. These countries represent the major regional centres for marine finfish culture. At present, a major feed source that is used to culture marine finfish in these countries is trash fish/low-value fish. Multispecies trials were undertaken by commercial farmers to establish the efficacy and environmental impacts of the use of trash fish/low-value fish and pellet feeds. Throughout the trial period, the farmers were provided with technical assistance from national counterparts, International/TCDC consultants, and a NACA monitoring team.

The trials were implemented using a standard methodology, with several farmers from each country participating in the programme. The stocking sizes and densities were standardized within farms and where possible across the farms. Within farms a random experimental design was applied with one or more of the cages being allocated to either trash fish/low-value fish or pellet feeds. The farmers were provided with training to maintain records on feed use, growth performance, growth rates, and the incidence of disease, mortalities, and morbidities. Water quality parameters were monitored at each of the farm sites, however the parameters that were monitored varied between the trial countries. The trials were terminated when the fish reached marketable size, then the fish were harvested and sold. In the event of high mortalities, the trials or the affected parts of the trials were terminated prematurely.

A number of commercial species were included in the growth and feed utilization trials. A summary of the species cultured at the different locations is provided in Table 1.

TABLE 1
Summary of the locations and species used for the farmers' participatory trials in the four countries

	China	Indonesia	Thailand	Viet Nam
Region/administrative area where the trials were undertaken	Guangdong (Canton)	Bandar Lampung	Phuket, Krabi and Phang Nga	Nha Trang
National institutions responsible for the implementation of the trial	Guangdong Provincial Aquatic Animal Epidemic Disease Prevention and Control Centre	Main Centre for Mariculture Development	Phuket Coastal Fisheries Research and Development Centre	Research Institute for Aquaculture No. 3
Culture species	Red snapper (*Lutjanus erythopterus*) Orange-spotted grouper (*Epinephelus coioides*)*	Brown-marbled grouper (*Epinephelus fuscoguttatus*)**	Barramundi (*Lates calcarifer*)*** Brown-marbled grouper (*Epinephelus fuscoguttatus*)	Snubnose pompano (*Trachinotus blochii*) Red snapper (*Lutjanus erythropterus*)

*Also known as green grouper; **also known as tiger grouper; ***also known as Asian seabass.

The pellet feeds that were used in the trials were country-specific, and supplied by local commercial aquafeed manufacturing companies (except in Viet Nam where a suitable local company could not be identified, and the EWOS feed company supplied the feed). Standard methods were used to determine the proximate composition and amino acid profile of the aquafeeds. Due to logistical constraints, the proximal composition of the trash fish/low-value fish was not established. In the absence of this data, the proximal composition of trash fish/low-value fish provided by Williams and Rimmer (2005) was used.

2.1 Proximate and amino acid composition

The proximate composition of pellet feeds was determined in triplicate using the following methods. Moisture was determined by drying to a constant weight (AOAC, 1980; p. 125, 7.003); crude protein was determined by a semi-automated Kjeldahl Method (AOAC, 1980; p. 127); lipid was determined by ether extraction using the Indirect Method (AOAC, 1980; p. 132, 7.056); crude fibre was determined by the Asbestos-Free Method (AOAC, 1980; p. 134); ash was determined by the Official Final Action Method (AOAC, 1980; p. 125); calcium was determined by the Official Final Action Method (30) (AOAC, 1980); and phosphorous was determined by the Photometric Method (41) (AOAC, 1980; p. 139). The amino acid composition of the aquafeeds was analysed in triplicate by a method based on AOAC (2005).

2.2 Performance parameters

Specific growth rate (SGR) and condition factor (C) were used to describe the growth and condition characteristics of the fish. Feed conversion ratio (FCR) was used as an indicator of feed efficiency. These indices were calculated as follows:

Specific growth rate (SGR; percentage body weight/day) = $\{(\ln w_2 - \ln w_1) \div (t_2 - t_1)\} \times 100$, where w_1 and w_2 refer to the weight at stocking time (t_1) and at harvest time (t_2), respectively.

Feed conversion ratio (FCR) = total amount of dry feed fed ÷ increase in wet biomass

$$\text{Condition factor (C)} = (W \div L^3)100$$

Where, W= weight of individual fish in g and L= total length of fish in cm

To evaluate the economic performance of the feed types, an economic assessment establishing the cost of production of one kilogramme of fish was undertaken. The following calculation was used:

Feed cost of production (cost/kg fish produced) = cumulative feed used (kg) x feed cost (price/kg)/(final biomass – initial biomass)

2.3 Statistical analysis

Statistical analyses were carried out to determine differences within each farm, between farms, and between feed types. Multivariate analysis of variance using Pillai-Bartlett trace (a conservative statistical test which is protective against the heterogeneity of variances across the covariance matrix and unequal sample sizes) was used to establish significant differences and interactions that were due to feed type and farm, and to control family wise errors when analysing the growth, feed performance or water quality variables. P values of < 0.05 were considered as significant, and all data were reported as mean ±standard error of means (SE). Where group differences were found, ANOVA using Games-Howell post hoc test (that is robust to unequal variances and small sample sizes) was used to determine differences within groups. All statistical analyses were carried out by using SPSS+ 13.0 for Windows (SPSS Inc. software.)

3. FARMERS' PARTICIPATORY TRIAL: CHINA

3.1 Materials and methods

3.1.1 Farmers

Five commercial fish farmers participated in the trials. These farmers operated between 36 and 173 cages (mean: 101 cages). The farmers cultured different species including red snapper (*Lutjanus erythopterus*), cobia (*Rachycentron canadum*), snubnose pompano (*Trachinotus blochii*), and grouper (*Epinephelus* spp.). For the purpose of the trial, red snapper and orange-spotted grouper were chosen as the culture species.

3.1.2 Trial design

Of the five farmers chosen for inclusion in the trial, three farmers cultured red snapper and two famers cultured the orange-spotted grouper. Two of the farmers were located in Liusha Port, Leizhou, Zhanjiang, Guangdong (Canton), with the remaining three farmers located in Techeng Island, Haitou Town, Xiashan District, Zhanjiang, Guangdong (Canton).

At each farm, either one or two cages were selected for each feed type. A total of five cages were allocated to each feed type for red snapper production, and three cages of each feed type to orange-spotted grouper production. The fish were weighed and measured at the beginning, the end, and every 14 days throughout the trial period. The trial was initiated in April 2009 and was continued until November 2009. The red snapper and orange-spotted grouper trials were terminated after 182 and 189 days respectively. The trials were terminated as a result of sudden drops in water temperature to 7°C. Depending on the farm, three sizes of cages were used in the trial. The cages were stocked with between 500 and 2 250 fish equating to stocking densities of 4 and 42 fish per m^3. The fish were stocked at an initial weight of between 6 and 20 g (Table 2).

3.1.3 Water quality

Throughout the trial, water quality parameters including temperature, pH and dissolved oxygen (DO) were monitored at 14 day intervals. Temperature and pH were measured using a HORIBA D-51E probe, and dissolved oxygen was measured using a HORIBA ON-51 probe.

TABLE 2
Fish stocking details of the farmers' participatory trial, China

Location of the farm	Species cultured	Cage size (m)	No. of replicates	No. of fingerlings stocked	Stocking density (no./m³)	Initial weight (g)
Liusha Port, Leizhou	Red snapper	3×6×3	1	2 000	37.0	12
Techeng Island	Red snapper	3×3×3	2	1 000	37.0	6
Techeng Island	Red snapper	3×3×3	2	1 000	37.0	6
Liusha Port, Leizhou	Orange-spotted grouper	3×6×3	1	2 250	41.7	20
Techeng Island	Orange-spotted grouper	5×5×5	2	500	4.0	20

3.1.4 Pellets

The compound aquafeeds that were used in the trial were supplied by the Zhanjiang Hengxing Feed Mill Co., Ltd., Zhanjiang, China. Due to logistical reasons, the proximate and amino acid composition analyses were only undertaken for the orange-grouper feed (pellet size: 5.5 and 11 mm) and for the red snapper feed (pellet size: 5.5 mm). The proximal analyses were undertaken according to the standard methods outlined in Section 1.2.1, and the results are presented in Table 3. The diets contained protein levels that ranged between 43–48 percent, and lipid levels that ranged between 8–13 percent.

The essential amino acid composition of the pellet feeds that were used in the trials is presented in Table 4. A high degree of variability in the amino acid composition of the different feed formulations was observed; it was noted that the main reasons for this variability could be due to the different formulations being suited to different size classes, life stages or species. The sum of the amino acids was high suggesting that good quality proteins had been used in the production of the pellets. The sum of the amino

TABLE 3
Proximate composition (% as fed basis) of selected commercial feeds* used in farmers' participatory trial, China

Proximate composition	Red snapper pellet (5.5 mm)	Orange-grouper pellet (5.5 mm)	Orange-grouper pellet (11 mm)
Moisture (% ± S.E)	5.0 ± 0.0	6.0 ± 0.0	6.0 ± 0.1
Crude protein (% ± S.E)	43.7 ± 0.3	43.5 ± 0.3	48.0 ± 0.1
Crude lipid (% ± S.E)	8.36 ± 0.12	9.29 ± 0.14	13.2 ± 0.3
Crude fibre (% ± S.E)	1.64 ± 0.03	1.56 ± 0.03	1.10 ± 0.02
Ash (% ± S.E)	14.7 ± 0.0	15.6 ± 0.0	11.5 ± 0.0
Calcium (% ± S.E)	1.62 ± 0.05	2.31 ± 0.01	2.89 ± 0.16
Phosphorous (% ± S.E)	1.35 ± 0.04	1.52 ± 0.04	1.69 ± 0.01

* Feed produced by Zhanjiang Hengxing Feed Mill Co., Ltd., Zhanjiang, China

TABLE 4
Essential amino acid (plus tyrosine) composition of selected commercial pellets used in farmers' participatory trial, China

Amino acid (%)	% of diet (as fed basis)			% of crude protein		
	Orange-grouper pellet (11 mm)	Red snapper pellet (5.5 mm)	Orange-grouper pellet (5.5 mm)	Orange-grouper pellet (11 mm)	Red snapper feed (5.5 mm)	Orange-grouper pellet (5.5 mm)
Arginine	2.33	2.44	2.09	6.14	7.26	5.29
Histidine	0.74	0.93	0.85	1.95	2.76	2.16
Isoleucine	2.09	1.52	2.90	5.50	4.51	7.33
Leucine	3.27	2.15	3.82	8.63	6.39	9.67
Lysine	2.00	2.88	2.73	5.28	8.56	6.90
Methionine	0.44	0.45	0.44	1.16	1.34	1.11
Phenylalanine	2.31	3.23	2.74	6.09	9.61	6.94
Threonine	2.06	1.02	1.43	5.43	3.02	3.63
Trytophan	0.10	0.05	0.06	0.26	0.15	0.14
Tyrosine	0.73	1.23	0.95	1.93	3.67	2.40
Valine	2.35	1.06	2.66	6.20	3.16	6.74

Marine cages in Zhanjiang, Guangdong, China. The farmers in this area culture a number of different species including red snapper, cobia, snubnose pompano, and different grouper species. They operate between 36 and 173 cages per farm with cage size varying from 54 to 125 m³.

Courtesy of FAO/M.C. Nandeesha

acids equated to 77 percent, 82 percent and 86 percent of the total percentage of crude protein, for the red snapper 5.5 mm, grouper 5.5 mm and grouper 11 mm pellet feeds, respectively. Had the sum of the amino acids been low (<60 percent of the recorded protein proximate composition), it would suggest that the amino acids had broken down or that non-amino acid sources of nitrogen were analysed in the proximate protein analysis.

3.1.5 Trash fish/low-value fish

The trash fish/low-value fish that was used during the trial primarily comprised torpedo scad (*Megalaspis cordyla*) and Japanese scad (*Decapterus maruadsi*). The chilled fish was purchased on a daily basis from local suppliers, minced, and fed to the fish. Due to logistical reasons, the fish was not analysed for proximate or amino acid composition.

3.2 Results

3.2.1 Farm by farm growth and feed utilization

The growth data derived from across all the farms indicated that feed type did not significantly affect the growth rates of the fish (P>0.05). Nevertheless, the red snapper that were fed the trash fish/low-value fish resulted in higher mean weight gains than those were fed the pellet feeds. A statistically significant difference in the final weight of orange-spotted grouper from one of the two trial farms was found, however, this result was not repeated at the other 'replicate' farm.

There were no significant differences between the growth and feed utilization parameters of the fish fed with pellets or trash fish/low-value fish (Table 5).

The mean individual fish weight over time at each farm and for each feed type is presented for red snapper and orange-spotted grouper in Figures 1 and 2 respectively. The fish grew at varying rates during the trial, and at times the fish weight decreased at some farms. The reduction in weight was most likely attributable to environmental stressors or the possible presence of disease.

TABLE 5

Farm by farm growth and feed utilization data of red snapper and orange-spotted grouper in farmers' participatory trial, China

Species, farm number and location	Number of replicates	Culture duration (days)	Feed type	Final weight (g)	Condition factor	SGR (%)	FCR	Survival (%)	Total biomass per cage (kg)	Amount of feed fed per cage (kg)	Feed cost of production (US$/kg fish)**
Red snapper											
1. Liusha Port, Leizhou	1	**182**	**Pellets**	461.1	1.71	0.807	1.34	77.5	714.2	960	1.61
			Trash fish	475.0	1.87	0.813	4.15	71.9	683.1	2 837.8	1.78
2. Techeng Island	2	**182**	**Pellets**	257.0 ± 12.0	1.62 ± 0.06	3.41 ± 0.75	1.27	55.6	282.6	360	1.52
			Trash fish	306.5 ± 3.5	1.73 ± 0.20	4.06 ± 1.3	7.23	87.4	536.3	3 879.2	3.11
3. Techeng Island	2	**182**	**Pellets**	352.5 ± 22.5	1.95 ± 0.04	2.30 ± 0.03	*	82	578.6		
			Trash fish	369.0 ± 6.0	1.79 ± 0.03	2.21 ± 0.03	4.07	85	627.4	2 554	1.75
Orange-spotted grouper											
1. Liusha Port, Leizhou	1	**196**	**Pellet**	266.7	1.65	0.44 (1)	2.7	39.6	237.4	640	3.24
			Trash fish	250	1.74	0.43 (1)	7.37	27.0	150.0	1 109	3.17
2. Techeng Island	2	**169**	**Pellets**	336.0 ± 16.0[b]	1.40 ± 0.07[b]	0.34 ± 0.03	2.44	28.0	114.0	280	2.93
			Trash fish	235.5 ± 0.5[a]	0.98 ± 0.00[a]	0.25 ± 0.0	17.2	34.0	66.4		7.40

* FCR could not be calculated due to an error in the trial in that farm and feed type.

** Cost incurred in Chinese Yuan Renminbi (CNY) converted to US$ based on an exchange rate of US$1 = CNY6.66

Note: Values in the same column with different superscripts are significantly different (P<0.05).

FIGURE 1
Mean weight of red snapper fed trash fish/low-value fish or pellets in three trial farms, China

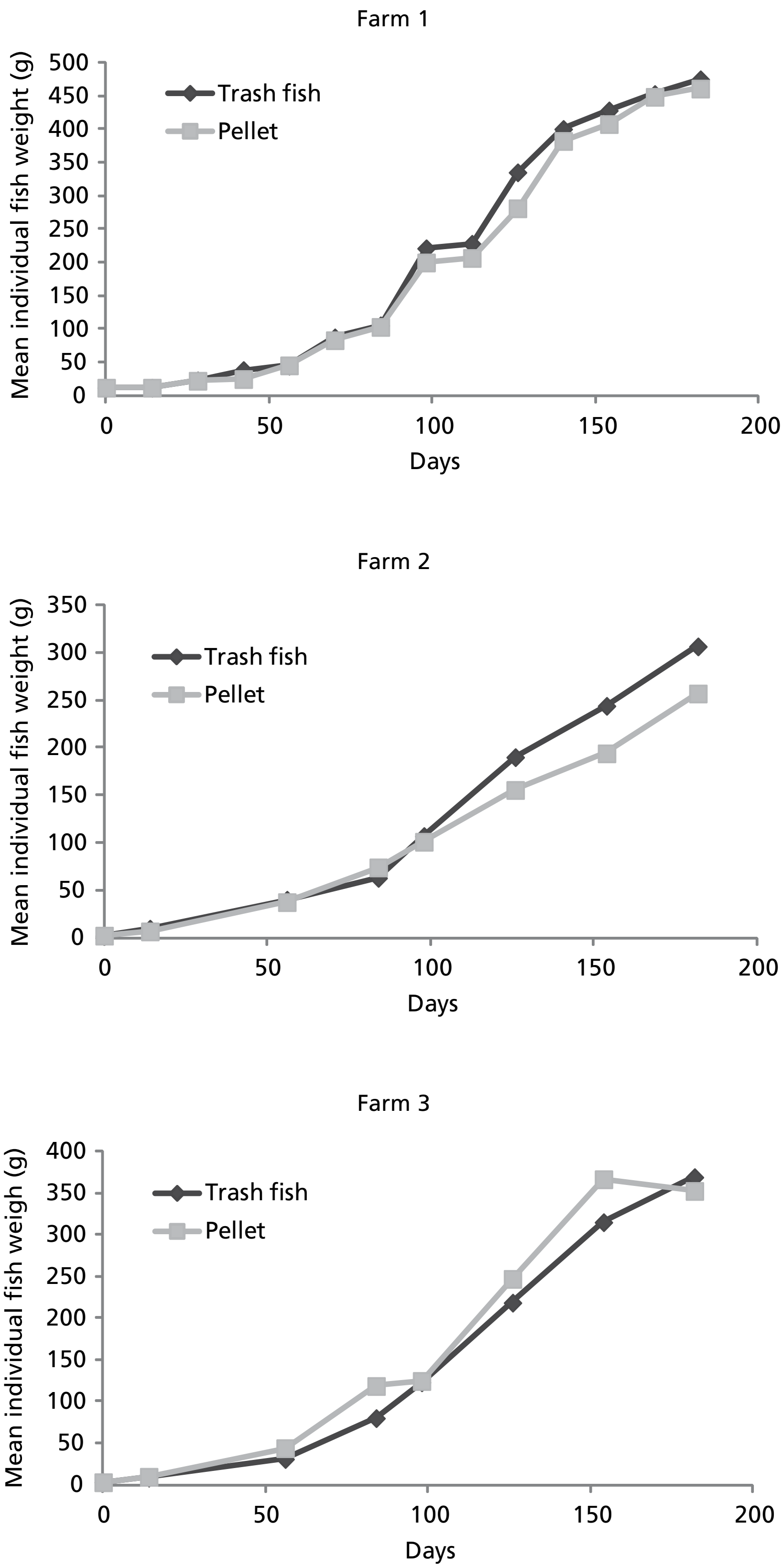
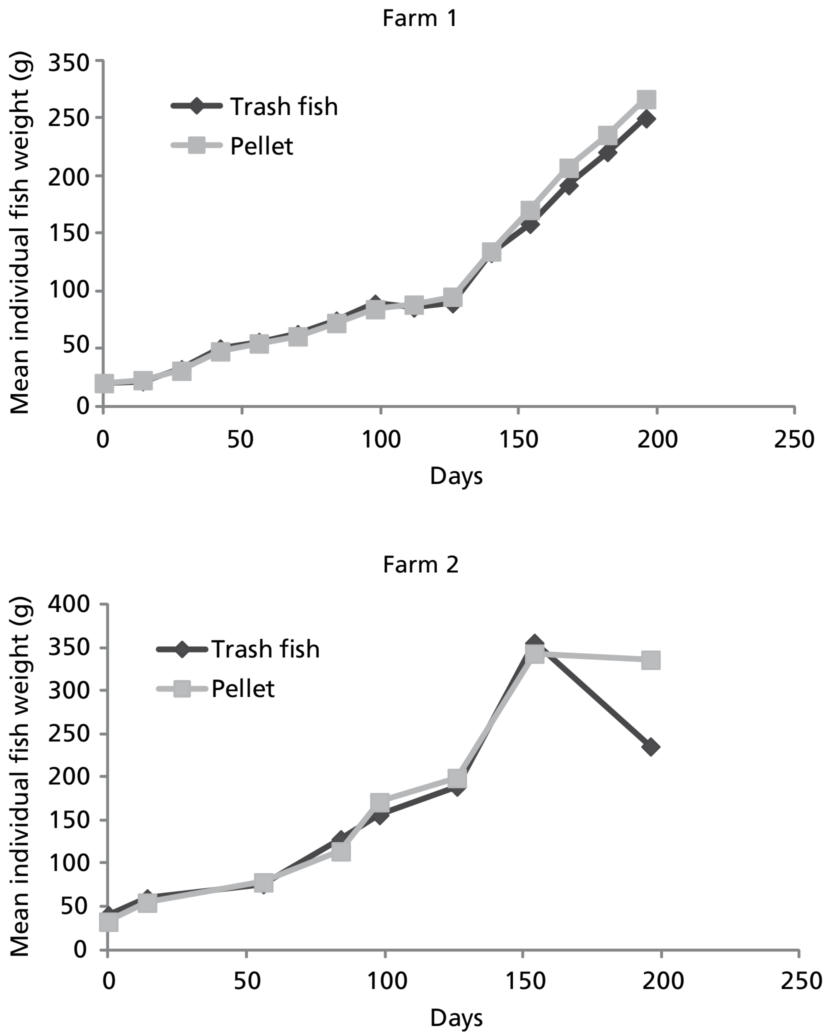


FIGURE 2
Mean weight of orange-spotted grouper fed trash fish/low-value fish or pellets in two trial farms, China



3.2.2 Overall growth and feed utilization

Orange-spotted grouper fed pellets showed significantly (P<0.05) higher mean weight gains than those fed the trash fish/low-value fish (Tables 5 and 6). No other growth performance or feed utilization parameters were found to be significantly different between the two dietary treatments. The FCRs of the red snapper that were fed pellets was 1.31, representing a far superior feed efficiency to the orange-spotted grouper that recorded an FCR of 2.57 (Table 6).

TABLE 6
Overall growth and feed utilization data of red snapper and orange-spotted grouper in farmers' participatory trial, China

Performance indicator	Orange-spotted grouper		Red snapper	
	Pellet	Trash fish	Pellet	Trash fish
Culture duration (days)	196	196	182	182
Final weight (g)	312.9 ± 24.9b	240.3 ± 4.8a	336.0 ± 38.7	365.2 ± 30.8
Final length (cm)	27.7 ± 1.2	27.3 ± 1.5	26.5 ± 0.9	27.3 ± 0.7
FCR	2.57 ± 0.13	12.33 ± 4.96	1.31 ± 0.04	5.15 ± 1.04
Survival (%)	36.9 ± 2.8	28.0 ± 0.2	71.7 ± 8.2	81.4 ± 4.8
SGR (%/day)	0.38 ± 0.04	0.31 ± 0.06	2.45 ± 0.53	2.67 ± 0.75

Note: Values in the same column with different superscripts are significantly different (P<0.05).

3.2.3 Economic performance

The feed costs associated with the production trial are presented in Table 7. The unit feed costs were US$1.2/kg for pellets and US$0.43/kg for trash fish/low-value fish. Based on the mean feed conversion ratios from the trials, the feed cost to produce 1 kg of orange-spotted grouper fed pellets was US$3.08. In contrast, the feed cost to produce 1 kg fish when using the trash fish/low-value fish diet was US$5.33. Similarly, the feed cost to produce 1 kg of red snapper using pellet feeds was US$1.6, while the use of trash fish/low-value fish increased feed costs to US$2.1.

TABLE 7

Feed cost associated with the production of one kilogramme of fish in farmer's participatory trials, China

Species	Orange-spotted grouper		Red snapper	
	Pellets	Trash fish	Pellets	Trash fish
FCR	2.57 ± 0.13	12.33 ± 4.96	1.31 ± 0.04	5.15 ± 1.04
Feed cost (US$/kg)	1.2	0.43	1.2	0.43
Feed cost of production (US$/kg fish)	3.08	5.33	1.6	2.1

Note: 1US$ = CNY6.66.

3.2.4 Water quality

A summary of the temperature, pH, and dissolved oxygen levels at the cage surface, bottom and outside the cages at each farm is presented in Table 8. No significant differences were observed in the water quality parameters between the sites when either the pellet or trash/low-value fish was used as a feed.

TABLE 8

Summary of the water quality parameters measured in farmers' participatory trial, China

Species, farm number and location	Temperature (°C)		pH		DO: cage surface (mg/l)		DO: cage bottom (mg/l)		DO: outside cage (mg/l)	
	Pellet	Trash fish	Pellet	Trash fish	Pellet	Trash fish	Pellet	Trash fish	Pellet	Trash fish
Red snapper										
1. Liusha Port, Leizhou	30.4 ± 0.7	30.4 ± 0.7	8.76 ± 0.04[a]	8.76 ± 0.05[a]	6.81 ± 0.15	6.79 ± 0.17	6.13 ± 0.14	6.11 ± 0.13	6.79 ± 0.14	6.70 ± 0.13
2. Techeng Island	29.0 ± 0.3	29.0 ± 0.3	8.32 ± 0.18[b]	8.31 ± 0.17[b]	6.45 ± 0.42	6.40 ± 0.41	6.36 ± 0.44	6.33 ± 0.42	6.58 ± 0.44	6.59 ± 0.44
3. Techeng Island	28.7 ± 0.4	28.7 ± 0.5	8.28 ± 0.15[b]	8.27 ± 0.15[b]	5.50 ± 0.19	5.56 ± 0.19	5.35 ± 0.18	5.40 ± 0.18	5.67 ± 0.26	5.67 ± 0.26
Orange-spotted grouper										
1. Liusha Port, Leizhou	30.0 ± 0.8	30.0 ± 0.8	8.74 ± 0.49[c]	8.73 ± 0.05[c]	6.78 ± 0.15	6.75 ± 0.16	6.07 ± 0.16	6.01 ± 0.16	6.73 ± 0.16	6.62 ± 0.15
2. Techeng Island	28.9 ± 0.4	28.9 ± 0.4	8.40 ± 0.15[d]	8.39 ± 0.14[d]	5.78 ± 0.15	5.88 ± 0.16	5.70 ± 0.15	5.79 ± 0.17	5.81 ± 0.14	5.81 ± 0.14

Individual water quality parameters between the two treatments (i.e., feed types) for each farm were not significantly (P>0.05) different.

During the trial period, the water temperature rose above 30°C in August, September, and October, and subsequently decreased in November. The average water temperature at the farms located in Leizhou was higher than those in Techeng Island. The pH values of the trial farms varied with the changes in water temperature, reaching a peak between August to October, with the highest value recorded at 9.63 in mid-October. The pH values recorded from the Techeng Island trial farms were lower than those recorded from the Leizhou trial farms. Over the course of the trial period, the pH values ranged from between 8.3 and 8.9. This represents a favourable pH range for marine cage farming. However, after late September and in early October, the pH values dropped to 7.5 and below at the Techeng Island area farms, indicting sub-optimal conditions for fish growth. Based on the location of the different farms, the pH was significantly higher at one of the red snapper farms (farm 1), and significantly different between orange-spotted grouper Farm 1 and orange–spotted grouper Farm 2.

3.2.5 Disease diagnosis and control

During the trial period, the trial farms became infected by several infectious and parasitic diseases. During the initial weeks of the trial (April–May), a *Benedeniasis* infection was observed, this was followed by a bacterial disease that occurred in June to August, and finally, the parasite *Cryptocaroniasis* was reported in October. A description of these disease outbreaks and the control measures that were applied is presented in Table 9.

Both the Leizhou Liusha Port and Zhanjing Techeng Island trial sites experienced disease outbreaks during the middle of the trial period; in contrast, the Leizhou site experienced disease problems earlier in the trials. The early onset of disease at this site was likely attributable to changes in water temperature at the site.

Parasitic diseases, especially *Benedeniasis,* affected the early stages of the trial (April to May). Fresh water bath treatments combined with potassium permanganate proved to be effective in controlling the disease.

The middle stages of the trial (June to August) were characterized by high water temperatures and bacterial diseases which caused significant impacts. During this period, both culture species experienced elevated mortality rates. For example, over 50 percent mortality was recorded in the orange-spotted grouper cages on Farms 1 and 2 in July and August.

Cryptocaryon irritans was the major pathogen that was present during the final stages of the trial. Various methods were attempted to control the disease. These included freshwater bath treatments and potassium permanganate treatments, the oral intake of traditional Chinese medicine (three-huang powder), and the use of antibiotics such as oxytetracycline and florfenicol. While these methods are simple to deploy, they were more effective in treating the parasitic diseases as opposed to the bacterial diseases.

It can be concluded that aquatic diseases remain a problem in China. Their incidence in the current trial represented a major factor that affected the outcomes.

TABLE 9

Disease outbreak and control during trial period between April and November 2009, China

Date of disease outbreak	Farm	Presumptive diagnosis	Disease control	Efficacy	Mortality rate
April 15	F1-Og	Parasitic disease (*Benedeniasis*)	fresh water bath mixed with potassium permanganate, 3 treatments	Good	0.70%
April 29	F1-Og	Parasitic disease (*Benedeniasis*)	fresh water bath mixed with potassium permanganate, 3 treatments	Fair	6.50%
May 7	F3-Rs & F2-Og	Parasitic disease (*Benedeniasis*)	fresh water bath	Good	3%~3.5%
May 19	F1-Rs	Parasitic disease (*Benedeniasis*)	fresh water bath mixed with potassium permanganate, 3 treatments	Good	3.4%~2.6%
May 19	F1-Og	Bacterial disease, skin ulcer in the body	fresh water bath mixed with potassium permanganate; oral intake of 3-huang herbal medicine	Good	3.40%
June 1	F1-Rs	Bacterial disease, skin ulcer on the body and tail	fresh water bath mixed with potassium permanganate,3 treatments; oral intake of 3-huang powder and antibiotics such as oxytetracycline and florfenicol	Poor	25~30%
July 25-Aug 4	F1-Og	Skin ulcer on the body and tail	fresh water bath mixed with potassium permanganate, treatment every 5 days; oral intake of 3-huang powder and antibiotics such as oxytetracycline and florfenicol	Poor	Overall mortality rate about 50%
Aug 18-31	F2-Og	Orange-spotted grouper identified with "bloats" - cause unknown	oral intake of 3-huang powder and antibiotics such as oxytetracycline and florfenicol	Poor	Daily mortality rate 2.2%, overall mortality rate about 50%
Oct 27	F2-Rs	Parasitic disease (*Cryptocaroniasis*)	fresh water bath mixed with potassium permanganate, treatment every 5 days; oral intake of 3-huang powder and antibiotics such as oxytetracycline and florfenicol	Fair	4.8~20%

Codes F1-Rs to F3-Rs denote farms 1 to 3 culturing red snapper, and F1-Og and F2-Og denote farms 1 and 2 culturing orange-spotted grouper.

Landing of trash fish/low-value fish in Zhanjiang, Guangdong, China. These low-value fish are primarily used for cage culture in this area.
Courtesy of FAO/Mohammad Hasan

3.3 Discussion

3.3.1 Pellet feed quality

Although the dietary requirements for red snapper (*Lutjanus erythropterus*) have yet to be established, the dietary requirements for a closely related species, the red mangrove snapper (*Lutjanus argentimaculatus*) have been reported (Liao *et al*., 2008). The red mangrove snapper has a dietary protein requirement of 41–43 percent, and a lipid requirement of 9–12 percent. Dietary protein levels in excess of 40 percent showed no net increase in growth when the lipid levels increased from 6 percent to 12 percent, and result in an FCR of 2.85 (Catacutan, Pagador and Teshima, 2001). Taking these dietary requirements into consideration, it is reasonable to suggest that the pellets used in the present study are suitably formulated for the red snapper.

The gross dietary requirements of orange-spotted grouper (*Epinephelus coioides*) are reported to be above 45 percent protein. At dietary lipid levels of between 11–14 percent, the optimal protein inclusion rate has been reported to be approximately 48 percent (Luo *et al*., 2004). Luo *et al*. (2005a) established that at a dietary protein level of 52 percent, the optimal lipid level was 10 percent.

The analysed crude dietary protein levels of the commercial diets used to feed the orange-spotted grouper in the current study appear to be lower than the optimal level in the 5 mm pellets, but were optimal in the 10 mm pellets. At these dietary protein levels, the lipid inclusion rates were slightly lower than optimal, and should have ranged between 11 and 14 percent.

There is limited information pertaining to the essential amino acid requirements of the orange-spotted grouper, and only the arginine, methionine and lysine requirements of the species have been reported. In a dietary formulation containing 48 percent protein, Luo *et al*. (2006a) reported a dietary arginine requirement of 2.7 percent. The arginine content of the commercial formulations used for the orange-spotted grouper production trials was marginally lower than the optimal level, and it is possible that this may have negatively affected the growth of the fish.

The optimal dietary methionine requirement for juvenile orange-spotted grouper has been reported at 1.31 percent of the diet. This level corresponds to 2.73 percent of the dietary protein (dry weight basis) when using a diet with a crude protein level of 48 percent, and a dietary cystine level of 0.26 percent (Luo *et al*., 2005b). The commercial diets used in the present study appear to contain less than half the optimal dietary methionine requirement for this species.

The optimal dietary lysine requirement for juvenile orange-spotted grouper has been reported as 2.83 percent of the diet when using dietary protein levels 49–52 percent (Luo *et al*., 2006b). The commercial 5.5 mm pelleted formulation used in the current study appears to contain sufficient dietary lysine, however, the formulation used in the larger pellets (11 mm pellets) appears to contain sub-optimal lysine levels.

A number of studies have used the amino acid profiles of the whole fish as indicators of the optimal amino acid balance required in their diets. Luo *et al*. (2008) fed green grouper an experimental diet that replicated its essential amino acid composition. The formulation performed well against other experimental diets, and proved superior to a diet formulated with brown fishmeal protein, red seabream egg protein and hen egg protein, however, white fishmeal proved a more effective protein source. Comparing the amino acid profiles of juvenile orange-spotted grouper reported by Millamena (2004) and the absolute levels of the amino acids in the dietary formulations used in the current study, the diets appear to be lacking in methionine. In this regard, methionine and lysine are limiting essential amino acids that are often found at relatively low levels in plant-based feed ingredients.

In general, the dietary formulations that were used in the trials were generally within the acceptable limits for aquaculture. However, the ash content of the red snapper and grouper feeds in the 5.5 mm pellet size was high (15.6 percent), and appeared to be approaching levels that are detrimental to growth. It has been observed that high ash fishmeal diets (>16 percent ash in white fishmeal) results in zinc deficiencies in cultured fish (NRC, 1993).

As the present trial used commercial diets that were not specifically designed for the trial species it is difficult to determine whether the formulations were limiting in terms of either their gross inclusion or specific nutrient inclusion levels. However, based on the proximate composition and amino acid composition of the dietary formulations, and what is known of the nutritional requirements of the species, it is likely that the dietary formulations, while not necessarily optimal, were suitable and should have produced acceptable growth responses.

It should be noted that the results of the amino acid analysis should be treated with caution as prior to analysis, the samples were refrigerated for some months. Under these storage conditions, it is possible that there was a change in the amino acid composition of the feeds. A change in the amino acid profiles could be attributed to the presence of microorganisms utilizing the amino acids, oxidization or the denaturing of the molecules.

3.3.2 Characterization of on-farm growth and feed utilization

An analysis of the trial data from individual farms indicated that both the orange-spotted grouper and red snapper accepted the pellet feeds throughout the trial period, and grew at similar or faster rates than the fish that were fed the trash fish/low-value fish. With the exception of the consumption and FCR data that differed between the diet type, and as a function of the high moisture content in the trash fish/low-value fish, the type of feed made little difference to the performance indices. The exception was the lower survival rates on Farm 2 where the red snapper were fed the pellet feed. The low survival at this farm was not observed at the replicate farms, and was attributed to a disease outbreak.

3.3.3 Overall growth and feed utilization

The overall results from across the all of the farms showed that orange-spotted grouper fed pellets outperformed those fed trash fish/low-value fish (Table 6). These results contrast to other studies, where either little difference was found between the feed types or where trash fish/low-value fish fed to groupers (*Epinephelinae* spp.) performed better than pellets (Chou and Wong 1985; Tacon *et al.*, 1991). The differential growth responses were most likely attributable to the poor quality of the trash fish/low-value fish that was available in China. The farmer survey and workshop discussions that were undertaken as component of the study revealed that the quality of the trash fish/low-value fish was a production issue for the farmers. Trash fish/low-value fish was obtained from the commercial trawlers that were primarily directed towards the fishmeal industry. The trawlers typically landed their catches after seven to fourteen days at sea. Generally, the trash fish/low-value fish was poorly preserved, was unsuitable for chopping, and had to be minced prior to feeding.

The initial stocking densities that were used in the trial was 37 fish per m^3 for red snapper cages and 42 and 4 fish per m^3 for the orange-spotted grouper cages. These stocking densities were lower than industry standards. Kongkeo *et al.* (2010) reports stocking densities of 50 fish per m^3 for both red snapper and orange-spotted grouper as the industry standard. Despite the marked differences between the initial stocking densities in the orange-spotted grouper trials, there were no observed differences in the survival rates between the stocking densities. This contrasts with Abdullah *et al.* (1987), who found that lower stocking densities resulted in lower survival, but higher growth rates, and James *et al.* (1998), who reported a decrease in survival with increasing stocking density. Chua and Teng (1978) reported lower growth and survival at higher stocking densities for Malabar grouper. To conclude, it is likely that the differential stocking densities that were applied to the different replicate groups influenced the results of the present study.

3.3.4 Economic performance

The relatively high FCRs of the fish fed the trash fish/low-value fish diet combined with its high price resulted in their relatively poor economic performance. In the current trial, the pellet feeds proved more economically efficient than the trash fish/low-value fish. The prices of the trash fish/low-value fish that was used in the current trial was reported to be relatively high. Kongkeo *et al.* (2010) reported prices of trash fish/low-value fish at half the price of that used in the current trial, and at these low prices it may make economic sense to use this feed than pellet feeds.

4. FARMERS' PARTICIPATORY TRIAL: INDONESIA

4.1 Materials and methods

4.1.1 Farmers

Six farmers participated in the trials. The farmers cultured a number of species including brown-marbled, humpback, and coral trout groupers, red snapper and cobia. Most farmers used the same cage size (3m x 3m x 3m). The number of cages in each farm varied between 45 and 120. The farms were located in Lampung Bay within 35 km of Bandar Lampung, Sumatra (Table 10).

TABLE 10

General characterization of the trial farms, Indonesia

No.	Cage detail		Species cultured	Location
	Number of cages	Cage size		
1	60	3 x 3 x 3 m	Brown-marbled grouper and humpback grouper	Ringgung
2	45	3 x 3 x 3 m	Brown-marbled grouper and humpback grouper	Maitem
3	70	3 x 3 x 3 m	Brown-marbled grouper and humpback grouper	Tegal Arum
4	100	3 x 3 x 3 m	Brown-marbled grouper, humpback grouper and cobia	Tanjung Putus
5	120	3 x 3 x 3 m	Brown-marbled grouper, humpback grouper, coral trout grouper, cobia, and red snapper	Pancur
6	50	3 x 3 x 3 m	Brown-marbled grouper and humpback grouper	Puhawang

4.1.2 Trial design

The trials were based on brown-marbled grouper (*Epinephelus fuscoguttatus*) that were fed either a commercial pellet feed or trash fish/low-value fish. The trials compared the growth, feed utilization, economic performance, and water quality parameters associated with using the two feed sources. The fish were stocked on the 4 April 2009, and the trial was terminated on 11 February 2010. The exception being one farm (Farm 6) where as a result of a storm incident, high mortalities were observed, and the trial had to be terminated in October 2009. Two cages were allocated to each feed type at each farm, equating to twelve replicates for each feed type. Uniform cages of 3 x 3 x 3 m were used, and the fish were stocked at a density of 500 juvenile fish per cage, equating to a stocking density of 18.5 fish per m^3. The initial mean weight of the fish was 17.2 g (Table 11). The fish were weighed and measured at the start of the experimental cycle, and at monthly intervals thereafter.

TABLE 11

Cage dimensions and stocking details in farmers' participatory trial, Indonesia

Parameters	Values
Cages per farm	2
Cage size (m)*	3 x 3 x 3
Initial fish weight (g)	17.2
Initial fish length (cm)	9.43
Initial fish condition factor	2.05
Stocking density (fish/cage)	500
Stocking density (fish/m^3)	18.5
Stocking density (kg/m^3)	3.2

*Length, width and depth.

4.1.3 *Water quality*

The parameters monitored were Secchi depth/water transparency, pH, salinity, dissolved oxygen (DO) and free ammonia. Water transparency was measured using a standard Secchi disc, pH using a WTW pH 3310 Set 2 pH meter, salinity using an ATAGO Hand refractometer (S/Mill-E), DO using a METTLER TOLEDO InLab 605 DO meter, and a modified indophenol blue method was used to measure ammonia (Sasaki and Sawada, 1980). Ammonia (NH_3), nitrite (NO_2), nitrate (NO_3), phosphate (PO_4), total organic matter (TOM) and total hardness were analysed according to standard methods (AOAC, 1980). Water quality was monitored on an *ad hoc* monthly basis, and was dependent on logistical circumstances and perceived water quality issues (i.e. water quality issues associated with algal blooms). Water quality parameters were monitored at the farm level, and no attempt was made to monitor the effect of feeding strategy on water quality.

4.1.4 *Pellet feed*

The pellet feed used in the Indonesian trial was Pakan kerapu (a grouper feed) from KRA PT JAPFA Comfeed Indonesia Tbk. The farmers fed to satiation during the trial period, and the feeding schedule was adjusted by the farmers according to their experience and the size of the fish.

The proximate and amino acid composition of the formulated feeds was analysed by the methods described in Section 2.1. It was established that the 3 mm and 5 mm pellet formulations contained approximately 50 percent crude protein and 14 percent lipid. In contrast, the 7 mm pellet formulation contained 43 percent crude protein, and while the crude protein level in the 10 mm pellet formulation was recorded at 49 percent, at 10 percent lipid, it contained the lowest lipid content of all the formulations (Table 12).

TABLE 12
Proximate composition (% as fed basis) of selected commercial feeds used in farmers' participatory trial, Indonesia

	KRA feed no. 3 (3 mm)	KRA feed no. 5 (5 mm)	KRA feed no. 7 (7 mm)	KRA feed no. 10 (10 mm)
Moisture (%)	7.0	8.3	8.1	6.9
Crude protein (%)	50.1	49.2	43.3	49.3
Crude lipid (%)	13.7	14.4	15.0	10.3
Crude fibre (%)	0.54	0.52	0.94	0.72
Ash (%)	13.2	12.9	10.4	12.4
Calcium (%)	3.36	3.36	2.44	3.16
Phosphorous (%)	2.09	2.02	1.67	1.77

KRA = Brand name of feed produced by JAPFA Comfeed Indonesia, PT. Suri Tani Pemuka, Indonesia.

The amino acid composition of the commercial diets is presented in Table 13. Some variability can be seen between the amino acid composition of different feeds that were fed to the different size classes. The sum of the amino acids on an 'as feed basis' equates to 75 percent, 91 percent, 81 percent and 84 percent of the analysed crude protein percentage, for the 3 mm, 5 mm, 7 mm and 10 mm pellet feeds respectively. This suggests that there was a low level of non-protein nitrogen in the proximate protein analysis.

4.1.5 *Trash fish/low-value fish*

Typically, trash fish/low-value fish is obtained through contracted suppliers, or middle men that purchase the product from fishers at landing sites, and subsequently transport it to the farms. Normally, different parts of the trash fish/low-value fish is fed to different species. For example, the tail and fillet parts of the fish are fed to the higher valued species such as the humpback or coral trout groupers, while the remaining portions that are of lower nutritional value (head, backbone and tail with the majority

TABLE 13
Essential amino acid (plus tyrosine) composition of selected commercial pellets used in farmers' participatory trial, Indonesia

Amino acid	% of diet (as fed basis)				% of crude protein			
	KRA feed no. 3 (3 mm)	KRA feed no. 5 (5 mm)	KRA feed no. 7 (7 mm)	KRA feed no. 10 (10 mm)	KRA feed no. 3 (3 mm)	KRA feed no. 5 (5 mm)	KRA feed no. 7 (7 mm)	KRA feed no. 10 (10 mm)
Arginine	2.33	2.35	2.28	2.31	6.16	5.26	5.98	5.56
Histidine	0.89	1.14	0.69	1.04	2.35	2.55	1.81	2.50
Isoleucine	2.62	2.87	2.27	2.19	6.92	6.43	5.96	5.26
Leucine	3.29	4.06	3.21	3.45	8.68	9.11	8.42	8.30
Lysine	3.24	3.48	3.33	3.49	8.55	7.79	8.75	8.40
Methionine	0.44	0.43	0.44	0.44	1.17	0.96	1.16	1.06
Phenylalanine	2.75	2.84	3.16	3.04	7.27	6.37	8.29	7.30
Threonine	1.55	1.96	1.72	2.06	4.09	4.40	4.52	4.95
Trytophan	0.12	0.09	0.10	0.19	0.31	0.19	0.27	0.47
Tyrosine	1.02	1.33	1.42	1.45	2.69	2.97	3.72	3.50
Valine	2.43	2.55	2.01	1.76	6.42	5.72	5.28	4.24

of the meat removed) are fed to the lower value species such as brown-marbled grouper, red snapper or cobia. During the experimental trial, the whole fish was fed to the brown-marbled grouper, and by doing so ensured that there was no bias in the quality of the feed that was provided to the replicate groups.

4.2 Results

4.2.1 Farm by farm growth and feed utilization

A summary of the growth performance and feed utilization at each farm is presented in Table 14. It was demonstrated the FCRs were consistently higher for those fish fed the trash fish/low-value fish in comparison with the fish fed the pellet feeds. However, this difference was only significantly different ($P<0.05$) at two farms (Farms 1 and 3). While the total harvest biomass per cage was higher in those cages that were fed the trash fish/low-value fish, the difference was not statistically significant ($P>0.05$). In terms of growth and feed utilization, there were no significant differences between the specific growth rates (SGR) of fish fed the two dietary treatments. The feed conversion ratio (FCR) was up to five times higher when the trash fish/low-value fish was used. Feed type did not significantly affect the condition factors of the fish at the end of the experimental period.

TABLE 14
Farm by farm growth and feed utilization data of brown-marbled grouper in farmers' participatory trial, Indonesia

Farm no.	Culture duration (days)	Feed type	Final weight (g)	SGR (%)	Condition factor	FCR	Survival (%)	Total biomass increase per cage (kg)	Total feed fed per cage (kg)	Feed cost of production (US$/kg fish)**
F1	313	Pellet	386.1 ± 66.7	0.35 ± 0.02	2.21 ± 0.15	2.21 ± 0.20[a]	55.9 ± 0.9	108 ± 20.4	225 ± 22.0	2.81
		Trash fish	447.6 ± 20.4	0.37 ± 0.01	2.22 ± 0.13	8.84 ± 0.62[b]	50.0 ± 4.0	112 ± 14.0	984 ± 54.2	4.88
F2	313	Pellet*	478.8*	0.37	2.12	2.27	58.2	139	316	3.01
		Trash fish	461.4 ± 47.4	0.37 ± 0.01	1.95 ± 0.02	5.50 ± 0.74	65.8 ± 0.8	152 ± 13.7	823 ± 36.2	3.04
F3	313	Pellet	383.8 ± 63.8	0.35 ± 0.02	2.21 ± 0.07	2.50 ± 0.42[a]	41.2 ± 8.2	76 ± 2.6	190 ± 25.4	3.32
		Trash fish	429.4 ± 9.4	0.36 ± 0.00	2.15 ± 0.01	4.76 ± 0.18[b]	41.1 ± 0.3	88 ± 1.3	420 ± 21.8	2.63
F4	313	Pellet	425.5 ± 55.5	0.36 ± 0.01	2.48 ± 0.09	2.11 ± 0.10	45.3 ± 4.7	95 ± 2.6	200 ± 4.49	2.58
		Trash fish	422.6 ± 72.6	0.36 ± 0.02	2.42 ± 0.14	4.19 ± 0.87	47.9 ± 8.3	104 ± 34.9	406 ± 55.9	2.31
F5	313	Pellet	365.8 ± 50.8	0.34 ± 0.02	2.66 ± 0.13	2.98 ± 0.95	47.0 ± 17.0	90 ± 43.0	228 ± 42.0	3.95
		Trash fish	472.7 ± 20.6	0.37 ± 0.01	2.26 ± 0.03	6.71 ± 0.77	40.6 ± 4.4	96 ± 14.6	636 ± 23.5	3.71
F6	189	Pellet	233.4 ± 10.6	0.48 ± 0.01	2.21 ± 0.15	2.71 ± 0.12[a]	21.6 ± 1.4	25 ± 2.77	68 ± 4.5[a]	3.60
		Trash fish	252.3 ± 10.25	0.50 ± 0.01	2.37 ± 0.13	6.33 ± 0.31[b]	21.7 ± 0.5	27 ± 1.7	173 ± 2.4[b]	3.50

Values in the same column for each farm with different superscripts are significantly different ($P<0.05$).

* Data from a single cage only as the other cages in the treatment at that farm was excluded due to high mortality and the early termination of the trial in the cage.

** Cost incurred in Indonesian Rupiah (IDR) converted to US$ based on an exchange rate of US$1 = IDR 9 047.

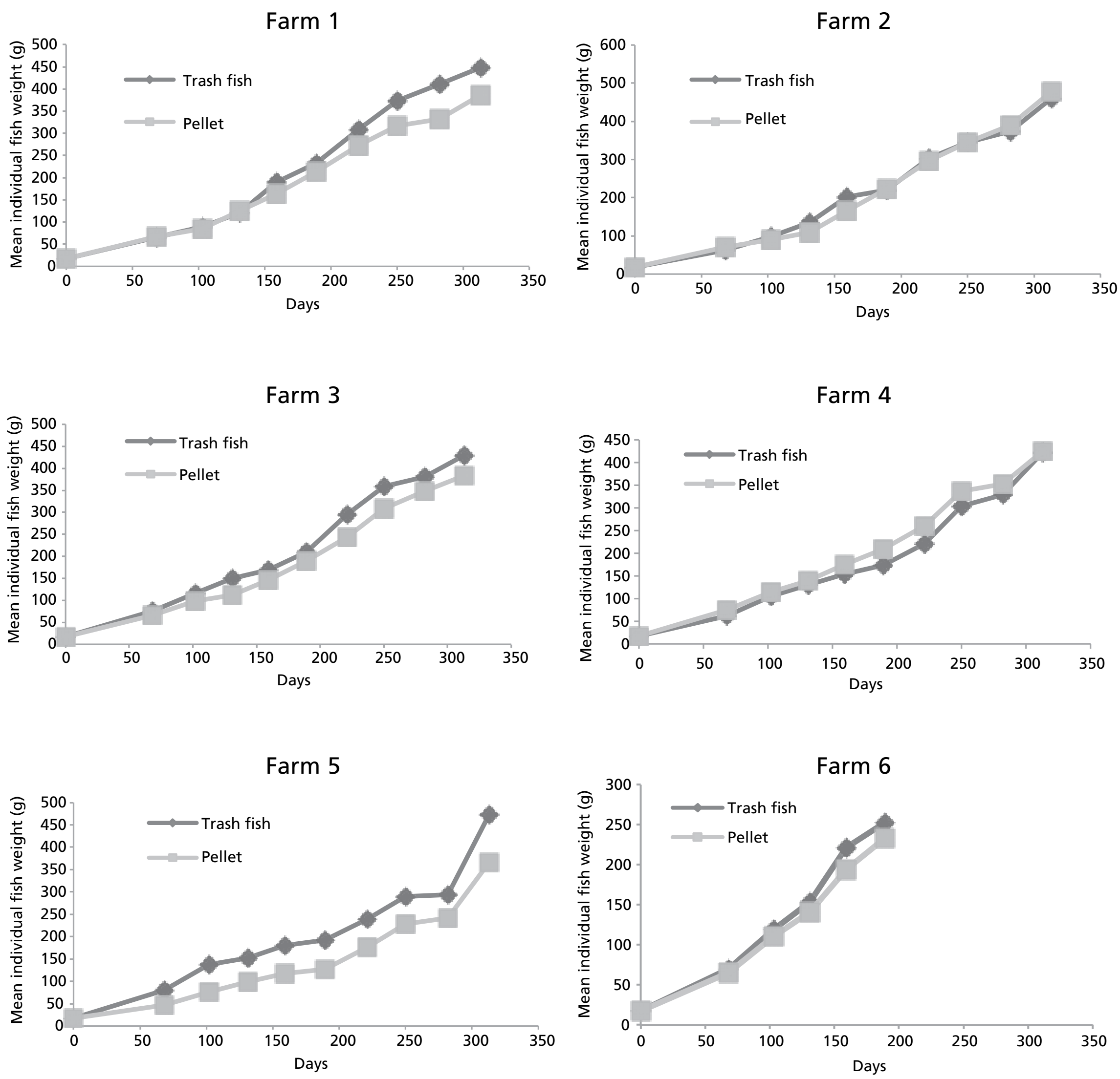
Cleaned net cages being dried in Lampung Bay, Bandar Lampung, Indonesia. Farmers generally dry and clean their nets after each harvest.
Courtesy of FAO/Mohammad Hasan

The mortality rates of the fish in the trial cages across all the farms were higher than typical industry standards. The high levels of mortality were associated with disease outbreaks, and sub-optimal weather including heavy rains and storms that resulted in water quality problems, and plankton blooms during the early stages of the trials. These plankton blooms also impacted other cages/farms in the area.

The mean weights of the individual fish fed either pellets or trash fish/low-value fish at each farm is presented in Figure 3.

FIGURE 3

Mean fish weight of brown-marbled grouper fed trash fish/low-value fish and pellets in six trial farms, Indonesia



4.2.2 Growth and feed utilization

The results show that at the end of the trial period, there were no significant differences between the mean length and weight of the fish, condition factors, survival rates, or specific growth rates, between the fish that had been fed the two dietary treatments (Table 15). As anticipated, those fish that had been fed the trash fish/low-value fish consumed significantly more feed, and expressed significantly poorer FCRs than those fed the pellet feeds.

TABLE 15

Overall growth and feed utilization data of brown-marbled grouper in farmers' participatory trial, Indonesia

Performance indicator	Feed type	
	Pellet	Trash fish/low-value fish
Final weight (g)	400.1 ± 23.3	446.7 ± 15.1
Final length (cm)	25.7 ± 0.6	27.3 ± 0.5
Condition factor	2.36 ± 0.08	2.20 ± 0.06
Survival (%)	48.6 ± 3.9	49.1 ± 3.4
SGR	0.35 ± 0.01	0.37 ± 0.00
FCR	2.41 ± 0.21[a]	6.00 ± 0.60[b]
Total biomass increase per cage (kg)	97.7 ± 10.2	110.6 ± 9.7
Total feed fed per cage (kg)	222.4 ± 15.7[a]	653.8 ± 76.4[b]

SGR = specific growth rate; FCR = feed conversion ratio.

Note: Values in the same row with different superscripts are significantly different ($P<0.05$)

4.2.3 Economic performance

The feed costs associated with production are presented in Table 16. The feed costs for the feed types were US$1.35/kg for pellets, and US$0.56/kg for trash fish/low-value fish. While the cost of the pellet feed was approximately 2.4 times that of the trash fish/low-value fish, the FCRs associated with the use of trash fish/low-value fish were more than double those of the fish that were fed the pellet feeds. As a result, the feed production cost associated with the two feed types were essentially similar.

TABLE 16

Feed cost associated with the production of one kilogramme of fish in farmer's participatory trials, Indonesia

	Pellets	Trash fish
FCR	2.41 ± 0.21[a]	6.00 ± 0.60[b]
Feed cost (US$/kg)	1.35	0.56
Feed cost for production (US$/kg fish)	3.32	3.4

Note: Values in the same row with different superscripts are significantly different ($P<0.05$)

4.2.4 Water quality

The trial farms were located in different embayments. Local water circulation patterns, adjacent land use patterns, and the presence of shrimp production ponds and other cage farming activities in the area affected the water quality, and in some cases resulted in the development of eutrophic conditions at individual sites. Generally, the water quality parameters that were measured throughout the trials were within the acceptable limits for grouper culture (Table 17). However, on one occasion low dissolved oxygen levels

TABLE 17

Summary of the water quality parameters measured in farmers' participatory trial, Indonesia

Farm no.	Temp. (°C)	pH	Salinity (ppt)	DO (mg/l)	NO_2 (mg/l)	NO_3 (mg/l)	NH_3 (mg/l)	PO_4 (mg/l)	TOM (mg/l)	Total hardness (mg/l)	Secchi depth (m)	Water depth (m)
F1	29.9 ± 0.3	8.14 ± 0.07	32.3 ± 0.2	5.55 ± 0.16	0.044 ± 0.018	0.044 ± 0.018	0.0697 ± 0.0484	0.0142 ± 0.008	30.01 ± 4.97	6818.4 ± 794.3	6.2 ± 0.4	9.9 ± 1.8
F2	30.3 ± 0.3	8.15 ± 0.06	32.0 ± 0.4	5.42 ± 0.16	0.012 ± 0.05	0.004 ± 0.001	0.062 ± 0.040	0.015 ± 0.005	29.9 ± 5.49	7087.0 ± 839.6	6.2 ± 1.4	14.2 ± 2.0
F3	29.9 ± 0.2	8.19 ± 0.04	32.2 ± 0.3	5.18 ± 0.29	0.009 ± 0.006	0.007 ± 0.003	0.0716 ± 0.0403	0.016 ± 0.006	28.04 ± 3.95	6586.5 ± 809.7	5.4	11.5
F4	29.7 ± 0.2	8.15 ± 0.03	32.1 ± 0.40	5.31 ± 0.22	0.063 ± 0.043	0.075 ± 0.057	0.0645 ± 0.0383	0.024 ± 0.011	27.80 ± 3.66	6938.4 ± 807.5	6.3 ± 0.3	13.7 ± 4.2
F5	29.8 ± 0.2	8.12 ± 0.05	32.2 ± 0.3	5.56 ± 0.18	0.019 ± 0.008	0.092 ± 0.060	0.0631 ± 0.0402	0.0317 ±0.013	29.57 ± 4.42	6776.8 ± 615.0	7.8 ± 0.6	15.2 ± 3.9
F6	30.1 ± 0.4	8.11 ± 0.15	31.7 ± 0.9	5.06 ± 0.05	0.038 ± 0.026	0.003 ± 0.002	0.1350 ± 0.1230	0.028 ± 0.012	29.48 ± 2.22	7187.2 ± 1481	5.5 ± 0.5	18.4 ± 0.2

TOM = total organic matter

Checking the health status of his culture stock (brown-marbled grouper) during growth monitoring, Lampung Bay, Bandar Lampung, Indonesia.

Courtesy of FAO/M.C. Nandeesha

(3.81 mg/l) were recorded. Phytoplankton blooms occurred during the initial two months of the trial. These blooms included harmful algae species, such as *Noctilluca* sp., *Thallasiosira* sp., *Pyrodinium* sp., and *Dinophysis* sp. In addition to the toxic algal species, algae was observed covering the fish gill surfaces of some of the fish, leading to asphyxiation. Furthermore, the algal blooms likely resulted in low dissolved oxygen levels during the early hours of the morning.

4.2.5 Disease diagnosis and monitoring

Disease events occurred in three stages during the trial - at the beginning of the trial (April-June 2009), the middle (October-November 2009) and the end of the trial (January-February 2010). At the beginning of the trial a disease outbreak resulted in very high fish mortalities. The disease events stabilized during the middle of the trial. During this period, some mortalities remained, and were attributed to poor water quality. Towards the end of the trial period, the disease status became more stable with much reduced mortality or an absence of mortality being reported across the trial farms. During the first month of the fish health monitoring, it was established that the grouper across all the sites were infected with parasites, bacteria and viruses. These observations were made as a result of liver, spleen, kidney, and gill analysis which showed positive results in Brain Heart Infusion Agar (BHIA) and Thiosulphate Citrate Bile Salt (TCBS) media.

The bacteria identified in the liver, spleen and kidneys comprised *Vibrio fluvialis, Vibrio alginoliticus* and *Vibrio vulnificus* and *Coccus* shaped bacteria. The gills were found to be infected with *Flavobacterium*. The analyses also established the presence of *Pseudorhabdosynochus* sp., Trematoda and *Trichodina* sp. parasites in the gills and skin. Based on virological analysis (Polymerization Chain Reaction, PCR), the fish raised in Tanjung Putus (farms 4 and 5) and Tegal Arum (farm 3), showed mild to moderate infections of viral nervous necrosis (VNN). Similarly, enlarged cell walls indicated the presence of a native viral infections. In contrast, farms 1, 2 and 6 showed no evidence of a VNN viral infection.

During the second month of monitoring, elevated infection rates of VNN and irridovirus were identified at some sites, resulting in a continuation of the high mortality rates. The virus was found in almost all the lymphoid target organs, including the spleen, kidney and thymus.

4.3 Discussion

4.3.1 Pellet feed quality

Giri, Suwirya and Marzuqi (2004) established the dietary requirements of brown-marbled grouper (*E. fuscoguttatus*), and found that juvenile fish (5–40 g) had a dietary requirement of 47 percent crude protein and 9 percent crude lipid, and larger (80–300 g) fish had a dietary crude protein requirement of 51 percent. In general the commercial pellets used in the trial appear to have contained sufficient crude protein levels to satisfy gross dietary requirements of marbled-brown grouper. However, the 7 mm pellet formulation appears to contain slightly less crude protein than the optimal level for the species. All the commercial pellets appear to contain above the optimal levels of lipid, particularly the 3 mm, 5 mm and 7 mm diets, and while it was not measured and thus cannot be confirmed, this may have resulted in increased rates of fat deposition in the fish.

4.3.2 Growth and feed utilization

The brown-marbled grouper were found to adapt easily to the pellet feeds, and grew on the formulations provided. With the exception of the FCRs which, as anticipated were significantly poorer in those fish fed the trash fish/low-value fish, there were no significant differences in the growth rates, survival and condition factors of the fish fed either the pellet feeds or the trash fish/low-value fish. The mortality rates during the trial were higher than could be considered standard for the industry. The presence of harmful algal blooms and diseases, notably at the start of the trial resulted in the high mortality rates, and as a result, the overall economic performance of the trials was compromised.

Due to its lower market value, the brown-marbled grouper are considered a secondary culture species, and in this regard, farmers prefer to maximize profits by culturing the higher value humpback grouper.

5. FARMERS' PARTICIPATORY TRIAL: THAILAND

5.1 Materials and methods

5.1.1 Farmers

The farmers that were selected for inclusion in the trials were chosen from the major mariculture production centres located along the Southwest coast of Thailand. A total of twelve farmers were selected for the trial. Of these farmers, four were selected from Phang Nga, four from Phuket, and four from Krabi. The selected farmers had over three years of experience in culturing either one or both of the trial species, and had used trash fish/low-value fish as a feed source.

5.1.2 Trial design

The trials were based on the culture of the barramundi (*Lates calcarifer*) and the brown-marbled grouper (*Epinephelus fuscoguttatus*). The trials compared the growth performance, feed utilization, economic performance, health status and water quality parameters associated with the use of commercially available pellet feeds and trash fish/low-value fish. The trial was initiated on 10 April 2009 and was continued until 7 January 2010.

At each farm, three cages were selected for each feed type, totalling 15 replicates for each feed type for the barramundi, and 21 replicates for each feed type for the brown-marbled grouper.

Fish were sampled at the start, the end, and at monthly intervals throughout the trial. While a range of different cage sizes were utilized in the trial, cages sizes at individual farms were similar. Fish stocking data is presented in Table 18.

The production performance of the fish across the different treatments was evaluated at both the farm level, and on a combined basis. The farm evaluation applied biometric information that was collected at the time of harvest - the time of harvest being quite different between farms. In order to standardize the culture period between the farms, the combined evaluation of all the farm data used the biometric information that had been recorded from the last time of common monitoring sampling.

5.1.3 Water quality

Water quality parameters were monitored at about 2 hours post-feeding and on a monthly basis. The parameters monitored were: salinity using an ATAGO hand refractometer (S/Mill-E), dissolved oxygen using a pro dissolved oxygen meter (METTLER TOLEDO InLab 605), and total ammonia using a modified indophenol blue method (Sasaki and Sawada, 1980).

5.1.4 Pellets

The commercially produced pellets used in the trial were supplied by the Thai Union Feed Mill Co., Ltd., Thailand (89/1 Moo 2, Tambol Kalong, Muang District, Samutsakorn). The feed that was supplied was a floating pellet that had been specifically formulated for barramundi. During the initial phase of the trial, the feed was fed to both the trial species. However, mid-trial, the diet that was fed to the brown-marbled grouper was changed to a sinking diet that had been formulated for cobia. The barramundi remained on the original formulation. The proximate and amino acid composition of the diets was analysed by the method described previously

TABLE 18
Cage dimensions and stocking details in farmers' participatory trial, Thailand

Farm	Species	Location	Cage size (m)*	Feed type	Number of fish/cage	Number of fish/m³	Initial weight (g)
F1-B	Barramundi	Phuket	3x 3.5x1.5	Pellet	144.0 ± 3.5	9.1±0.2	33
				Trash fish	147.7 ± 1.2	9.4 ± 0.1	33
F2-B	Barramundi	Phang Nga	3x3x1.8	Pellet	141.7 ± 4.5	8.7 ± 0.3	33
				Trash fish	149.7 ± 0.9	9.2 ± 0.1	33
F3-B	Barramundi	Phang Nga	3x3x1.8	Pellet	139.7 ± 13.0	8.6 ± 0.8	33
				Trash fish	151.0 ± 0.6	9.3 ± 0.1	33
F4-B	Barramundi	Phang Nga	2.5x2.5x2.5	Pellet	150.7 ± 0.9	9.6 ± 0.1	33
				Trash fish	148.0 ± 3.0	9.5 ± 0.2	33
F5-B	Barramundi	Phang Nga	2.5x2.5x2.5	Pellet	153.3 ± 2.9	9.8 ± 0.2	33
				Trash fish	148.0 ± 3.5	9.5 ± 0.2	33
F1-Bg	Brown-marbled grouper	Phuket	2.5x2.5x1.5	Pellet	141.3 ± 9.0	15.1 ± 1.0	31
				Trash fish	128.3 ± 27.7	13.7 ± 2.95	31
F2-Bg	Brown-marbled grouper	Krabi	2.8x2.8x2	Pellet	143.3 ± 5.7	12.2 ± 0.5	40
				Trash fish	146.3 ± 3.2	12.4 ± 0.3	40
F3-Tg	Brown-marbled grouper	Phuket	3x3x2	Pellet	146.7 ± 0.3	8.2 ± 0.0	31
				Trash fish	148.3 ± 1.7	8.2 ± 0.1	31
F4-Bg	Brown-marbled grouper	Krabi	3x3x2	Pellet	145.0 ± 1.7	8.1 ± 0.1	40
				Trash fish	150.0 ± 2.1	8.3 ± 0.1	40
F5-Bg	Brown-marbled grouper	Phuket	2.5x2.5x1.5	Pellet	143.7 ± 2.4	15.3 ± 0.3	31
				Trash fish	129.0 ± 15.9	13.8 ± 1.7	31
F6-Bg	Brown-marbled grouper	Krabi	3x3x2	Pellet	149.7 ± 1.3	8.3 ± 0.1	40
				Trash fish	137.7 ± 10.4	7.6 ± 0.6	40
F7-Bg	Brown-marbled grouper	Krabi	3x3x2	Pellet	148.3 ± 3.2	8.2 ± 0.2	40
				Trash fish	154.7 ± 4.3	8.6 ± 0.2	40

* Length, width and depth;

Note: Codes F1-B to F3-B denote farm 1 to farm 3 culturing barramundi; codes F1-Bg to F7-Bg denote farm 1 to farm 7 culturing brown-marbled grouper.

in Section 2.1. The proximate composition of the pellets used in the trial is provided in Table 19. Depending on the formulation, the pellets contained between 7–9 percent moisture, 40–45 percent crude protein, 8–11 percent crude lipid, and 11–13 percent ash. The amino acid composition of the formulations is provided in Table 20.

TABLE 19
Proximate composition (% as fed basis) of selected commercial pellets* used in farmer's participatory trial, Thailand

Composition	Barramundi pellet (3–4 mm)	Barramundi pellet (6 mm)	Barramundi pellet (9 mm)	Barramundi pellet (12 mm)
Moisture	6.74	6.96	8.39	9.28
Crude protein	45.19	43.27	40.06	45.27
Crude lipid	9.79	9.76	8.16	10.86
Crude fibre	0.71	1.11	1.52	1.25
Ash	12.25	11.74	11.28	12.67
Calcium	3.22	2.53	2.43	2.52
Phosphorous	1.56	1.41	1.25	1.47

* Feed produced by Thai Union Feed Mill Co., Ltd., Muang District, Samutsakorn, Thailand.

5.1.5 Trash fish/low-value fish

While the species composition of the trash fish/low-value fish that was used varied almost daily, on any given day it tended to be the same species, and fresh. The main species that were fed during the trials were yellowstripe trevally (*Selaroides leptolepis*), goldstripe sardinella (*Sardinella* spp.) and Indian mackerel (*Rastrelliger* spp.). Typically, the fish were purchased from landing sites, however some farmers caught the fish themselves. Two trial farmers reported using fish processing waste that was comprised of the fish carcasses without the fillet potion.

Marine cages cages in Phang Nga, southern Thailand. In this area, barramundi are mostly cultured in cages.
Courtesy of FAO/Mohammad Hasan

TABLE 20
Essential amino acid (EAA) composition of selected commercial pellets used in farmer's participatory trial, Thailand

Amino acid	% as feed basis				% of crude protein			
	Barramundi pellet (3-4 mm)	Barramundi pellet (6 mm)	Barramundi pellet (9 mm)	Barramundi pellet (12 mm)	Barramundi pellet (3-4 mm)	Barramundi pellet (6 mm)	Barramundi pellet (9 mm)	Barramundi pellet (12 mm)
Arginine	2.23	2.10	1.66	2.12	5.60	5.63	5.89	4.73
Histidine	0.65	0.61	0.18	1.00	1.63	1.63	0.65	2.23
Isoleucine	2.53	2.49	1.86	2.98	6.37	6.65	6.60	6.64
Leucine	3.32	3.39	2.41	4.25	8.35	9.06	8.53	9.46
Lysine	2.87	2.77	1.98	2.83	7.23	7.40	7.01	6.30
Methionine	0.44	0.44	0.45	0.43	1.11	1.18	1.59	0.96
Phenylalanine	3.17	2.79	2.33	2.94	7.98	7.45	8.26	6.55
Threonine	1.73	1.38	1.14	1.48	4.35	3.68	4.05	3.30
Trytophan	0.16	0.04	0.02	0.01	0.39	0.11	0.07	0.02
Tyrosine	1.19	1.16	0.93	1.25	3.00	3.09	3.29	2.78
Valine	2.16	2.37	1.56	3.69	5.44	6.33	5.52	8.22

5.2 Results

5.2.1 Water quality parameters

The water quality parameters monitored at the trial farms are presented in Table 21. The parameters were all within the acceptable range for barramundi and brown-marbled grouper culture.

Water temperature was not recorded during the trials. However in late December 2009, water temperature decreased rapidly to 22°C at some farm sites (F1-Bg and F3-Bg).

TABLE 21
Summary of the water quality parameters measured in farmers' participatory trial, Thailand

Code	Feed type	Salinity (ppt)	Secchi depth (cm)	DO: cage surface (mg/l)	DO: cage bottom (mg/l)	DO: outside cage (mg/l)	NH_3: inside cage (mg/l)	NH_3: outside cage (mg/l)
F1-B	Pellet	31.3 ± 0.6	81.2 ± 12.8	5.16 ± 0.28	5.14 ± 0.29	5.18 ± 0.29	0.0992 ± 0.0300	0.0883 ± 0.0339
	Trash fish	31.3 ± 0.6	81.2 ± 12.8	5.14 ± 0.30	5.10 ± 0.33	5.11 ± 0.29	0.0949 ± 0.0342	0.0918 ± 0.0403
F2-B	Pellet	24.1 ± 2.3	90.7 ± 11.9	5.19 ± 0.26	5.17 ± 0.21	5.17 ± 0.23	0.0639 ± 0.0201	0.0593 ± 0.0210
	Trash fish	24.1 ± 2.3	90.7 ± 11.9	5.18 ± 0.22	5.11 ± 0.20	5.19 ± 0.19	0.0590 ± 0.0217	0.0599 ± 0.0224
F3-B	Pellet	25.1 ± 2.3	90.7 ± 11.9	5.20 ± 0.20	5.10 ± 0.22	5.17 ± 0.23	0.0611 ± 0.0246	0.0501 ± 0.241
	Trash fish	25.1 ± 2.3	90.7 ± 11.9	5.15 ± 0.21	5.10 ± 0.21	5.17 ± 0.21	0.0541 ± 0.0236	0.0578 ± 0.244
F4-B	Pellet	23.4 ± 2.5	85.7 ± 10.8	5.48 ± 0.15	5.34 ± 0.16	5.50 ± 0.14	0.0807 ± 0.0351	0.0669 ± 0.0365
	Trash fish	23.4 ± 2.5	85.7 ± 10.8	5.50 ± 0.17	5.35 ± 0.21	5.51 ± 0.18	0.0633 ± 0.0366	0.0696 ± 0.0356
F5-B	Pellet	23.4 ± 2.5	87.1 ± 11.9	5.54 ± 0.20	5.30 ± 0.20	5.43 ± 0.13	0.0782 ± 0.0426	0.0828 ± 0.0425
	Trash fish	23.4 ± 2.5	87.1 ± 11.9	5.56 ± 0.15	5.15 ± 0.25	5.49 ± 0.14	0.0844 ± 0.0426	0.0854 ± 0.0424
F1-Bg	Pellet	32.0 ± 0.3	118 ± 10	5.93 ± 0.16	5.92 ± 0.18	6.04 ± 0.19	0.0773 ± 0.0387	0.0639 ± 0.0402
	Trash fish	32.0 ± 0.3	118 ± 10	5.95 ± 0.15	5.89 ± 0.17	6.00 ± 0.17	0.0764 ± 0.0392	0.0638 ± 0.0402
F2- Bg	Pellet	28.7 ± 1.0	142 ± 14	4.68 ± 0.19	4.53 ± 0.20	4.73 ± 0.19	0.0582 ± 0.0133	0.0524 ± 0.0127
	Trash fish	28.7 ± 1.0	142 ± 14	4.65 ± 0.18	4.52 ± 0.24	4.66 ± 0.19	0.0903 ± 0.0313	0.0610 ± 0.0149
F3-Bg	Pellet	32.1 ± 0.4	138 ± 9	5.70 ± 0.25	5.87 ± 0.24	5.91 ± 0.21	0.0914 ± 0.0363	0.0443 ± 0.0137
	Trash fish	32.1 ± 0.4	138 ± 9	5.90 ± 0.23	5.92 ± 0.23	5.94 ± 0.22	0.0704 ± 0.0331	0.0301 ± 0.0102
F4-Bg	Pellet	28.9 ± 1.0	140 ± 15	4.72 ± 0.15	4.62 ± 0.17	4.69 ± 0.15	0.0812 ± 0.0252	0.0721 ± 0.0255
	Trash fish	28.9 ± 1.0	140 ± 15	4.67 ± 0.17	4.54 ± 0.17	4.60 ±0.16	0.0706 ± 0.0226	0.0807 ± 0.0266
F5-Bg	Pellet	32.1 ± 0.4	161 ± 10	6.06 ± 0.15	6.06 ± 0.16	6.12 ± 0.12	0.0697 ± 0.0311	0.0458 ± 0.0268
	Trash fish	32.1 ± 0.4	161 ± 10	6.11 ± 0.14	6.10 ± 0.19	6.25 ± 0.17	0.0632 ± 0.0285	0.0443 ± 0.0271
F6-Bg	Pellet	29.8 ± 0.73	154 ± 13	5.05 ± 0.12	4.99 ± 0.16	5.04 ± 0.18	0.0513 ± 0.0140	0.0521 ± 0.0162
	Trash fish	29.8 ± 0.73	154 ± 13	5.16 ± 0.13	5.00 ± 0.16	5.10 ± 0.17	0.0611 ± 0.0153	0.0457 ± 0.0130
F7-Bg	Pellet	29.7 ± 0.7	154 ± 13	4.82 ±0.19	4.85 ± 0.19	4.81 ± 0.20	0.0755 ± 0.0159	0.0583 ± 0.0149
	Trash fish	29.7 ± 0.7	154 ± 13	4.80 ± 0.20	4.93 ± 0.18	4.80 ± 0.21	0.0755 ± 0.0187	0.0611 ± 0.0142

Note: codes F1-B to F3-B denote farm 1 to farm 3 culturing barramundi; codes F1-Bg to F7-Bg denote farms 1 to 7 culturing brown-marbled grouper.

Individual water quality parameters between two treatments (i.e., feed types) for each farm were not significantly (P>0.05) different.

A cage farmer mixing oil and a small amount of water to pellets before feeding to his culture stock, Phang Nga, southern Thailand. Additional additives such as vitamin and mineral premix are often added during mixing.

Courtesy of FAO/Mohammad Hasan

The rapid decrease in temperature resulted in mortalities at those farms, and for this reason, the data from these farms was excluded from the growth and feed utilization analysis.

The use of either the trash fish/low-value fish or pellet feeds did not significantly ($P>0.05$) affect the water quality at the farms. However, a significant difference ($P<0.05$) in salinity was observed between Farm 1 (31.3±0.6 ‰) that cultured barramundi and the other barramundi farms.

At the surface, bottom and outside of the cages of the brown-marbled grouper farms, significant differences were found in the salinity, transparency and dissolved oxygen levels ($P<0.05$). No significant differences were found in the ammonia concentrations between the inside and the outside of the cages ($P>0.05$). Water quality parameters did not differ significantly between the farms, and the feed type did not significantly affect the water quality.

5.2.2 Farm by farm growth and feed utilization

The results of the barramundi feed trial are presented in Table 22. Feed type did not significantly affect the specific growth rates ($P>0.05$). At three of the five farms, the volume of the trash fish/low-value fish that was fed was significantly greater than the volume of pellets that were fed. The FCRs were generally higher in those groups that were fed the trash fish/low-value fish diets, and were significantly so at those farms that recorded significantly higher trash fish/low-value fish consumption. With the exception of one farm (Farm 2), there were no significant differences in final mean weights of the fish at the end of the trial period. In the Farm 2, the fish fed the pellet feed grew significantly better than those fed the trash fish/low-value fish. However, it should be noted that large variations in growth and feed utilization performance were observed across the farms.

The mean fish weights recorded during the trial period at each farm and for each feed type are presented for brown-marbled grouper and barramundi in Figures 4 and 5 respectively. It is evident that while the barramundi grew steadily throughout the trial period, at times and at some farms, the brown-marbled grouper lost weight.

TABLE 22

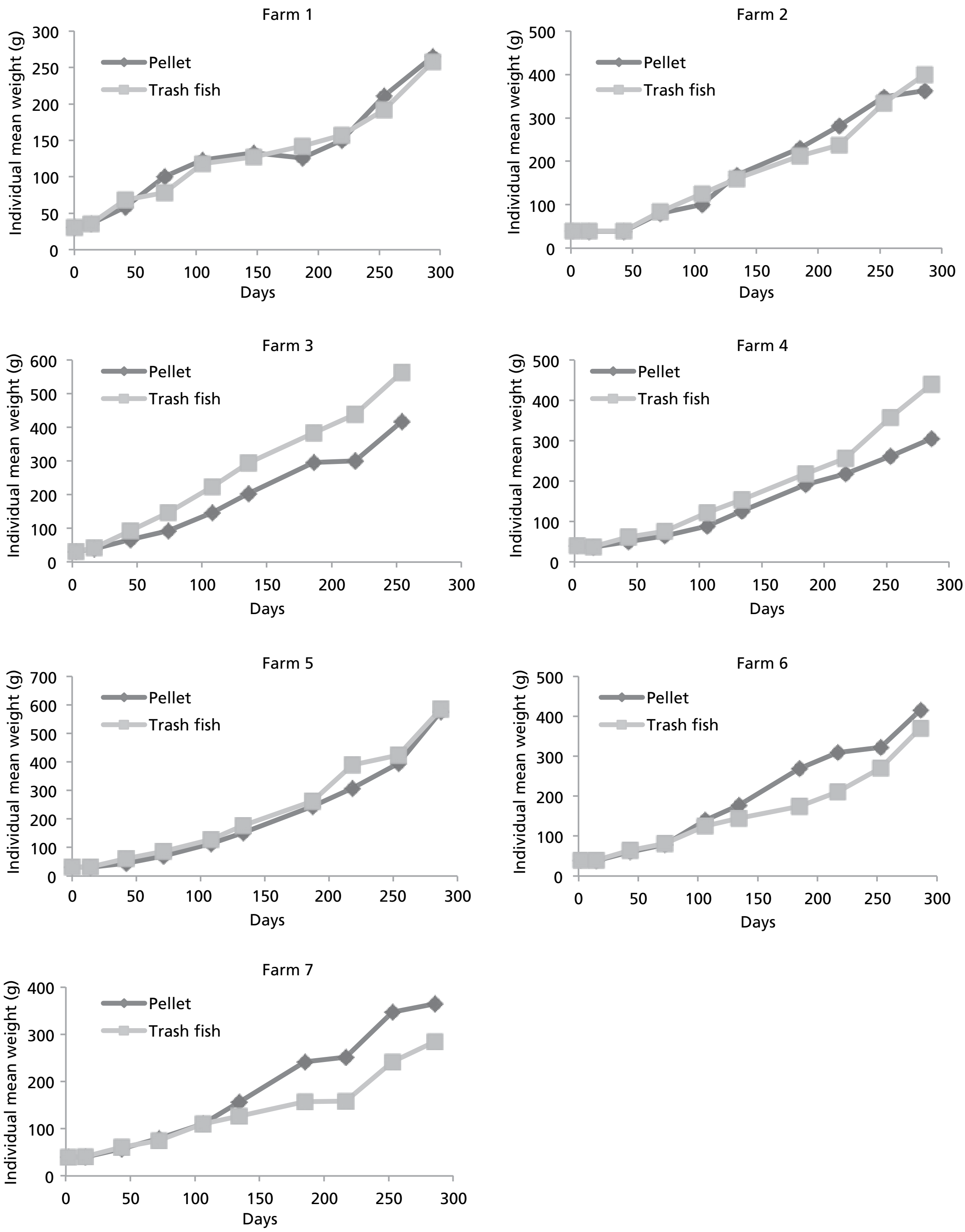
Farm by farm growth and feed utilization data of barramundi in farmers' participatory trial, Thailand

Code	Culture duration (days)	Feed type	Final weight (g)	Final length (cm)	Condition factor	SGR	FCR	Survival (%)	Total final biomass/ cage (kg)	Total feed fed/cage (kg)	Feed cost of production (US$/kg fish)*
F1-B	223	Pellet	622.8 (19.7)	35.7 (0.3)	1.35 (0.01)	1.36 (0.01)	2.59 (0.04^{a})	92.6 (1.2)	91.6 (2.1)	225.5 (8.2^{a})	3.44
		Trash fish	652.1 (19.5)	36.0 (0.3)	1.38 (0.02)	1.32 (0.00)	14.2 (0.20^{b})	93.2 * (1.4)	84.9 (1.1)	1 135.1 (0.3^{b})	4.69
F2-B	183	Pellet	687.0 (21.6^{b})	36.1 (0.37)	1.43 (0.01^{b})	1.58 (0.03)	2.6 (0.08)	92.4 (1.8)	77.9 (2.2)	191.7 (5.4)	3.46
		Trash fish	601.4 (14.6^{a})	35.4 (0.30)	1.34 (0.01^{a})	1.53 (0.01)	3.25 (0.40)	84.1 (9.3)	67.9 (6.7)	208.5 (0.8)	1.07
F3-B	183	Pellet	660.6 (17.1)	35.8 (0.28)	1.43 (0.01^{b})	1.55 (0.03)	2.74 (0.11)	95.4 (1.0)	75.0 (9.8)	192.2 (17.5)	3.64
		Trash fish	679.7 (20.1)	36.6 (0.37)	1.37 (0.01^{a})	1.54 (0.02)	2.62 (0.06)	93.4 (2.5)	78.3 (1.7)	199.3	0.90
F4-B	134	Pellet	528.5 (17.8)	32.9 (0.32)	1.46 (0.01)	2.07 (0.03)	2.60 (0.06^{a})	100	79.6 (3.6)	193.7 (6.0^{a})	3.46
		Trash fish	532.4 (15.8)	33.3 (0.31)	1.43 ± 0.01	2.07 (0.04)	5.16 (0.28^{b})	98.2 (1.0)	77.4 (3.9)	371.7 (0.1^{b})	1.70
F5-B	134	Pellet	519.2 (13.0)	32.9 (0.29)	1.44 (0.01)	2.06 (0.02)	2.65 (0.06^{a})	100	79.7 (3.6)	191.6 (8.9^{a})	3.52
		Trash fish	533.3 (15.8)	33.3 (0.32)	1.42 (0.01)	2.08 (0.02)	5.14 (0.07^{b})	100	78.8 (1.1)	371.6^{b}	1.69

Note: codes F1-B to F3-B denote farm 1 to farm 3 culturing barramundi. For each farm the mean (±SE) is given for the three cages used for each feed type.

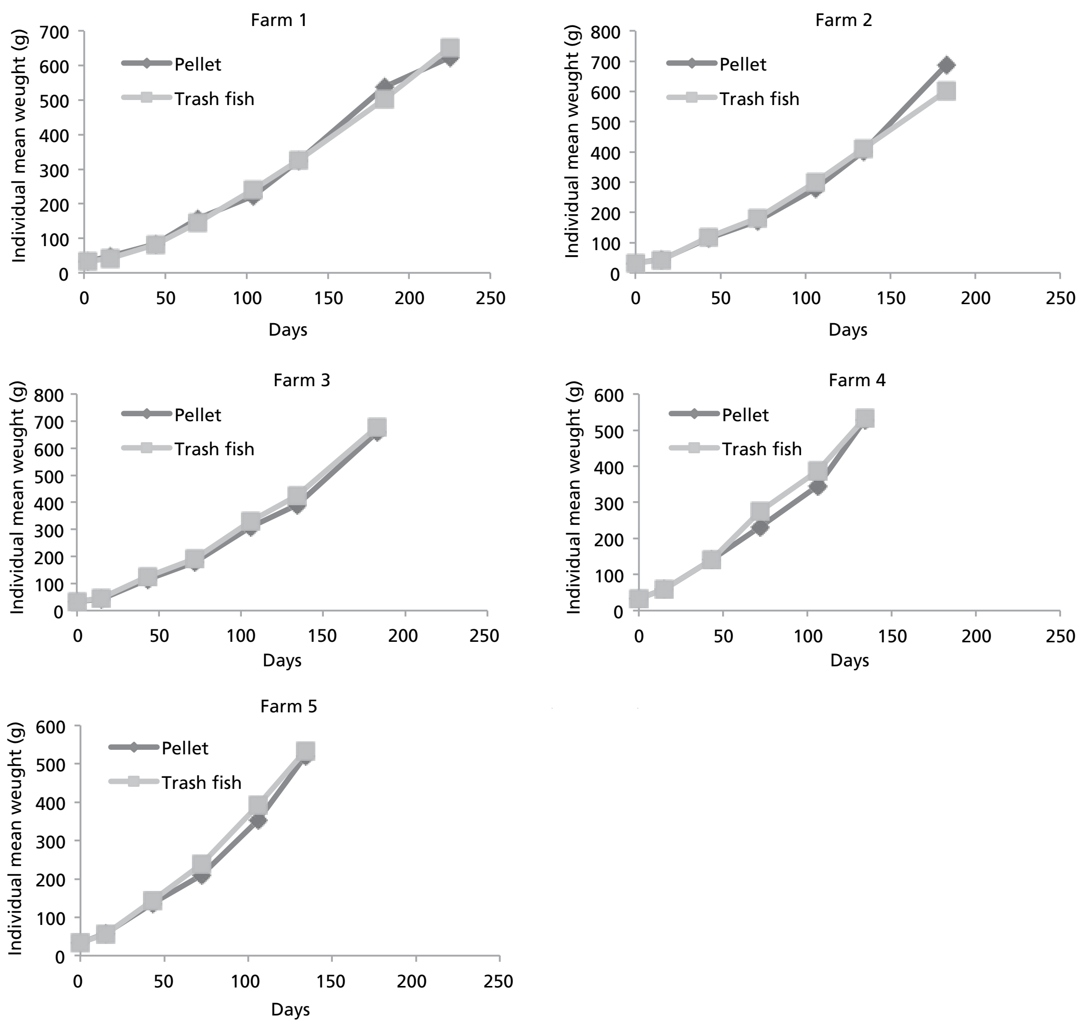
* Cost incurred in Thai Baht (THB) converted to US$ based on an exchange rate of US$1 = THB35.2

FIGURE 4
Mean weight of brown-marbled grouper fed trash fish/low-value fish or pellets in five trial farms, Thailand



The results from the brown-marbled grouper trial are presented in Table 23. No consistent trend in the growth performance of the fish fed the two dietary treatments could be established. The growth performance of the fish fed the trash fish/low-value fish diet was sometimes significantly better than that of the fish fed the pellet feeds. Sometimes growth rates were similar, and at other times growth was significantly reduced. Across all the treatments, the volume of trash fish/low-value fish that was fed was greater than the volume of pellet feed that was fed, however, the difference in

FIGURE 5
Mean weight of barramundi fed trash fish/low-value fish or pellets in five trial farms, Thailand



feed volumes used was only significant in five out of the seven farms. A similar tend was observed with the FCRs, however again, the FCRs were only significantly higher in the trash fish/low-value fish treatments in four out of the seven farms. The growth rate and final mean weights were found to be significantly different at four farms. Two of the farms reported significantly higher growth and final weights when using the pellet feeds, with the remaining two farms reporting significantly higher growth and final weights when using the trash fish/low-value fish. It should be noted that large differences were observed between all the parameters measured in the trial.

5.2.3 Overall growth and feed utilization

The growth and feed utilization of barramundi and brown-marbled grouper across all the farms is presented in Table 24. No significant differences were found in the weight, survival, growth rate or biomass increase per cage in the barramundi that were fed either feed. However, significant differences were observed in the length of the barramundi, with those fed the pellet feeds being significantly shorter than those fed the trash fish/low-value fish. As a consequence of the differential length data, the condition factors reported from the fish fed the pellet feeds were significantly greater. The food conversion ratios were significantly lower in those fish fed the pellet feeds than that were fed the trash fish/low-value fish.

TABLE 23

Farm by farm growth and feed utilization data of brown-marbled grouper in farmers' participatory trial, Thailand

Code	Culture duration (days)	Feed type	Final weight (g)	Final length (cm)	Condition factor	SGR	FCR	Survival (%)	Total final biomass/ cage (kg)	Total feed fed/ cage (kg)	Feed cost of production (US$/kg fish)*
F1-Bg	294	Pellet	265.2 (12.7)	22.9 (0.3)	2.13 (0.02)	0.68	21.8	35.8	30.7	670.0	28.99
		Trash fish	257.8 (11.7)	22.9 (0.3)	2.30 (0.16)	0.69	47.7	55.3	45.7	2176.8	15.74
F2-Bg	284	Pellet	365.8 (18.7)	25.1 (0.44)	2.25 (0.02)	0.78	1.89	77.6	114.9	217.3	2.51
		Trash fish	399.1 (20.2)	26.0 (0.36)	2.21 (0.03)	0.76	5.17	76.8	110.6	572.2	1.70
F3-Bg	251	Pellet	417.9 (14.5^{a})	26.4 (0.3^{a})	2.24 (0.03)	0.99 (0.01^{a})	14.1 (2.9)	26.9 (3.3)	10.4 (2.5)	131.1 (3.7^{a})	18.75
		Trash fish	563.1 (16.3^{b})	29.0 (0.3^{b})	2.28 (0.02)	1.16 (0.03^{b})	25.5 (10.5)	39.7 (9.6)	30.3 (9.9)	574.9 (3.3^{b})	8.42
F4-Bg	284	Pellet	305.7 (13.7^{a})	23.6 (0.4^{a})	2.24 (0.02)	0.65 (0.0^{a})	2.9 (0.3^{a})	76.0 (3.9^{a})	22.6 (2.1^{a})	64.5 (1.1^{a})	3.85
		Trash fish	439.7 (15.3^{b})	26.9 (0.3^{b})	2.21 (0.02)	0.81 (0.0^{b})	7.0 (0.3^{b})	89.5 (1.4^{b})	47.8 (2.1^{b})	334.2 (0.2^{b})	2.31
F5-Bg	287	Pellet	576.9 (17.8)	28.7 (0.3)	2.39 (0.03)	0.95 (0.01)	4.2 ± (0.0^{a})	61.1 (2.2)	37.6 (0.4)	157.6 (1.3^{a})	5.59
		Trash fish	586.3 (19.3)	28.9 (0.3)	2.39 (0.03)	0.98 (0.01)	38.1 (2.5^{b})	66.5 (2.1)	39.4 (3.7)	1484.5 (69.7^{b})	12.57
F6-Bg	284	Pellet	416.3 (17.3^{b})	26.3 (0.3)	2.24 (0.03^{b})	0.75 (0.02^{b})	2.78 (0.16^{a})	86.0 (1.1)	36.9 (2.1^{b})	101.8 (0.2^{a})	3.70
		Trash fish	370.5 (14.0^{a})	25.9 (0.3)	2.08 (0.01^{a})	0.65 (0.01^{a})	5.26 (0.07^{b})	73.4 (4.6)	20.2 (0.4^{a})	106.3 (1.3^{b})	1.74
F7-Bg	284	Pellet	363.9 (16.1^{b})	25.5 (0.4^{b})	2.14 (0.03)	0.74 (0.02^{a})	2.90 (0.28^{a})	78.6 (9.2)	31.8 (3.3)	90.4 (0.1^{a})	3.86
		Trash fish	284.8 (11.8^{a})	23.7 (0.3^{a})	2.11 (0.02)	0.63 (0.01^{a})	4.99 (0.14^{b})	82.6 (7.5)	23.9 (2.0)	118.8 (6.8^{b})	1.65

Note: codes F1-Bg to F7-Bg denote farm 1 to farm 7 culturing brown-marbled grouper.
Note: For each farm the mean (±SE) comprises the three cages used for each feed type.

* Cost incurred in Thai Baht (THB) converted to US$ based on an exchange rate of US$1 = THB35.2.

TABLE 24

Overall growth and feed utilization data of barramundi and brown-marbled grouper in farmers' participatory trial, Thailand

Performance indicator	Barramundi		Brown-marbled grouper	
	Pellet	Trash fish	Pellet	Trash fish
Final weight (g)	432.6 ± 7.9 CV = 0.274	445.6 ± 8.3 CV = 0.278	408.8 ± 9.9 CV = 0.351	417.3 ± 10.0 CV = 0.349
Final length (cm)	30.9 ± 0.17^{a}	31.5 ± 0.18^{b}	25.9 ± 0.2	26.3 ± 0.2
Condition factor	1.42 ± 0.01^{b}	1.39 ± 0.01^{a}	2.25 ± 0.01^{b}	2.20 ± 0.01^{a}
Survival (%)	97.8 ± 0.8	98.4 ± 0.6	75.6 ± 3.2	77.9 ± 3.0
SGR	1.92 ± 0.04	1.94 ± 0.03	0.77 ± 0.03	0.77 ± 0.04
FCR	2.55 ± 0.08^{a}	5.51 ± 1.09^{b}	3.09 ± 0.21	13.17 ± 3.97
Total biomass increase/cage (kg)	62.3 ± 4.2	65.4 ± 3.4	38.6 ± 6.6	38.8 ± 6.8
Total feed fed per cage (kg)	144.7 ± 10.8^{a}	302.8 ± 43.0^{b}	112.3 ± 12.9	515.7 ± 158.6
Feed cost of production (US$/kg fish)	2.61 ± 0.08^{b}	1.42 ± .27^{a}	3.49 ± 0.23	3.74 ± 1.13

An exchange rate of 35.2 THB to 1 US$ was applied.

Note: Mean values (±SE) for each parameter is presented. CV= Coefficient of variation. Values in rows with different superscripts are significantly different ($P < 0.05$). The brown-marbled grouper from trials F1-Bg & F3-Bg have been excluded from the analysis as a result of the mass mortalities that occurred during the trial.

The growth and feed utilization data from the brown-marbled grouper farm trials was combined (251-254 days after stocking). Between dietary treatments, there were no significant differences between the final weights, length, FCR, SGR and survival rates. The only significant difference that was observed was the condition factor of the fish, where those fish that had been fed the pellet feeds were in a significantly better condition at the end of the trial period.

5.2.4 Economic performance

The feed costs associated with the production of the brown-marbled grouper and barramundi are presented in Table 25. The feed costs associated with the production of one kilogramme of brown-marbled grouper was not significantly different when either pellets or trash fish/low-value fish were used. However, for barramundi production, the feed cost was considerably lower when trash fish/low-value fish were fed.

TABLE 25
Feed cost associated with the production of one kilogramme of fish in farmer's participatory trials, Thailand

Species	Brown-marbled grouper		Barramundi	
	Pellets	Trash fish	Pellets	Trash fish
FCR	3.09 ± 0.21	13.17 ± 3.97	2.55 ± 0.08[a]	5.51 ± 1.09[b]
Feed cost (US$/kg)	1.33	0.33	1.33	0.33
Feed cost of production (US$/kg fish)	4.12	4.38	3.07	1.67

5.3 Discussion

5.3.1 Water quality

The water quality parameters that were recorded over the trial period were within a suitable range for barramundi and brown-marbled grouper culture. The exception being two of the brown-marbled grouper production sites. Due to the poor water quality at these sites, the production data from these farms was excluded from the analysis.

Few differences were found in water quality parameters from those cages that were fed either the trash fish/low-value fish or the pelleted diets. It is reasonable to conclude that although the addition of feed to the water column would have influenced water quality, the type of feed applied *per se* did not have a detectable influence on water quality. Furthermore, the trial sites were at different locations on the coast, and locational differences appear to have had more impact on water quality than feed type - particularly so between the brown-marbled grouper culture sites.

5.3.2 Pellet feed quality

The dietary protein requirement for barramundi (*L. calcarifer*) has been reported at 46 percent (Williams and Barlow, undated) or between 45–50 percent (Boonyaratpalin, 1989). The diet formulation that was used in the current trial was specifically formulated for the species. The dietary protein levels of the 3–4 mm and 12 mm pellet diets were measured at 45 percent crude protein, and were within the optimal range reported for the species. However, at 43 percent and 40 percent crude protein respectively, the 6 mm and 9 mm pellet diets were slightly below the optimal crude protein level for the species.

As outlined in Section 4.3.1, the crude protein and lipid requirements for the brown-marbled grouper are reported as 47–51 percent crude protein and 9 percent lipid (Giri, Suwirya and Marzuqi, 2004). As commercially formulated brown-marbled grouper diets were not available, the trials initially used the formulations that were designed for the barramundi. The barramundi formulations that were used appear to have had crude protein levels that were between 2–11 percent lower than that recommended for brown-marbled grouper. The crude lipid concentrations were within ±1 percent of the optimal levels for the species. The lower levels of protein in the commercial barramundi formulations, particularly the 6 mm and 9 mm diets, at 43 percent and 40 percent protein respectively, could have proved limiting to growth. Though the proximal composition of the cobia formulation that was used in the study was not determined, the protein level reported by the feed manufacturer was 41 percent, representing a lower inclusion level than the optimal for the brown-marbled grouper. Thus, this formulation may also have compromised growth.

5.3.3 Farm by farm growth and feed utilization
Inconsistencies in the feed management practices by the farmers may have played a more significant role in determining feed efficiency and growth patterns than did the feed type. During the trial, the farmers were instructed to apply their usual husbandry and feed management practices. In terms of feed management, the normal practice was to feed *ad libitum*. If the present study had applied scientific experimental design principles as opposed to farm-based trial methods, the management impact on the FCRs and growth rates would not have been observed. While the standardization of feed management practices in the experimental design may have resulted in quantifiable differences being demonstrated in feed use and utilization, the results of the present study suggest that feed management practices remain central to the establishment of on-farm feed efficiencies, and in terms of the current study, may be a more important factor in determining feed efficiencies than the feed types themselves.

5.3.4 Overall growth and feed utilization
Contrary to popular belief both species accepted the pellet feeds. However, the barramundi accepted the pellets more readily than the brown-marbled grouper. It should be noted that the average FCRs that were attained during the trials were high, and as it is possible that they were likely attributable to the relatively poor level of feed management. The results further highlight the need to improve on-farm feed management practices.

The difference in the FCRs reported from those fish fed trash fish/low-value fish or the pellet feed can be attributed to the relatively high moisture content of trash fish/low-value fish. Despite the differences in the FCRs, it is worth noting that good growth rates can be attained for both barramundi and brown-spotted grouper using either feed type. The results of the present study are similar to those reported by Rachmansyah *et al.* (2009) and Tacon *et al.* (1991) who found that brown-marbled grouper, barramundi, and the greasy grouper (*Epinephelus tauvina*) showed similar or better growth rates, FCRs (on a dry weight basis), and protein efficiency ratios when fed trash fish as opposed to formulated moist or dry pellets.

Despite the low survival rates and the relatively high FCRs recorded in the grouper trials for both feed types, there is scope to improve grouper husbandry practices in the region. The current trials with the pellet feeds have generated interest in the use of these feeds, and has provided some insight for the farmers to consider their future use.

It should also be noted that the provision of free seed and feed for the trial may have promoted a degree of complacency on the part of some farmers. This may have lead to some degree of wastage (e.g. over feeding), resulting in high FCRs, and lower than anticipated economic efficiencies.

6. FARMERS' PARTICIPATORY TRIAL: VIET NAM

6.1 Materials and methods

6.1.1 Farmers
Ten farmers participated in the trials. Each farmer owned between 4 and 70 cages, and the cages differed in size. Cages were between 36 to 112 m^3. During the trial, the farmers cultured snubnose pompano (*Trachinotus blochii*) with one farmer also culturing red snapper (*Lutjanus erythropterus*). At each farm, one cage was allocated to either trash fish/low-value fish or commercial pellets (Table 26).

TABLE 26
Cage dimensions in farmers' participatory trial, Viet Nam

Farm	Size of cage (m)	Cage volume (m³)	No. of cages	Trial species
1	3.5x3.5x5	61.2	2	Snubnose pompano
2	4x4x5	80	2	Snubnose pompano
3	3x3x4	36	2	Snubnose pompano
	3x3x4	36	2	Red snapper
4	3x3x5	45	2	Snubnose pompano
5	3.5x3.5x5	61.2	2	Snubnose pompano
6	3.5x3.5x5	61.2	2	Snubnose pompano
7	4x4x7	112	2	Snubnose pompano
8	4x4x4	64	2	Snubnose pompano
9	4x4x4.5	72	2	Snubnose pompano
10	3x3x4	36	2	Snubnose pompano

6.1.2 *Trial design*

The fish were weighed and measured at the start, the end, and at 15-31 day intervals throughout the trial. The trial was initiated on 23 April 2009 and was continued until 8 April 2010. The trial with snubnose pompano was terminated after 310–314 days, while the trial with red snapper was terminated after 351 days. The initial weight of the fish and the stocking densities that were used in the trial are presented in Table 27.

TABLE 27
Summary of stocking parameters in farmers' participatory trial, Viet Nam

	Snubnose pompano		Red snapper	
	Pellets	Trash fish	Pellets	Trash fish
Initial weight (g)	5.3	5.3	78.0	78.0
Stocking density (no. of fish/cage)	750 ± 75	750 ± 75	250	250
Stocking density (no. of fish/m³)	11.9 ± 1.0	11.9 ± 1.0	6.9	6.9

6.1.3 *Water quality*

Water quality parameters were monitored approximately every four weeks. The parameters monitored included salinity, dissolved oxygen, and pH. Salinity was measured using an ATAGO Hand refractometer (S/Mill-E). Dissolved oxygen was measured using a pro dissolved oxygen probe (METTLER TOLEDO InLab 605), and pH was measured using a SevenGro Pro pH/ion probe (METTLER TOLEDO 9040718).

6.1.4 *Pellets*

The commercially manufactured pellet feeds that were used in the trial were provided by EWOS. They were sourced from Norway, and transported to the trial site in Na Trang City via Ho Chi Minh City. The feed was transported in a number of shipments, and comprised two different pellet sizes - 3 mm and 5 mm pellets. The high fishmeal content used in the feed resulted in the formulation being relatively expensive (US$1.8/kg). The proximate and amino acid composition of the pellet was analysed by the method as described in Section 2.1.

Proximate composition and amino acid composition of the 5 mm pellets used in the trial is presented in Tables 28 and 29 respectively. The diet was high in crude protein (about 50 percent), had a moderate lipid level (about 10 percent), and the sum of the amino acids accounted for a high proportion of the protein proximate composition.

TABLE 28
Proximate composition (% as fed basis) of EWOS pellet used in farmer's participatory trial, Viet Nam

Composition	EWOS pellet (5 mm)
Moisture	5.9
Crude protein	49.6
Crude lipid	10.6
Crude fibre	2.09
Ash	7.91
Calcium	1.75
Phosphorous	1.49

6.1.5 *Trash fish/low-value fish*

Trash fish/low-value fish species used by the trial farmers is listed in Table 30. Prior to feeding, the trial farmers purchased the trash fish/low-value fish from trash fish

Farmer's wife feeding barramundi fingerlings in cages, Phang Nga, southern Thailand. Wild caught fingerlings are often kept in smaller cages before being transferred to larger grow out cages.
Courtesy of FAO/Mohammad Hasan

suppliers. They purchased the fish on a daily basis. Whole trash fish were chopped and fed to the trial fish once a day, and mostly in the morning.

TABLE 29
Amino acid (AA) composition of the commercial pellet used in farmers' participatory trial, Viet Nam

Amino acid (%)	% as feed basis	% of protein
Arginine	2.32	5.00
Histidine	0.57	1.23
Isoleucine	3.43	7.38
Leucine	4.26	9.16
Lysine	2.41	5.18
Methionine	0.44	0.95
Phenylalanine	3.36	7.23
Threonine	2.23	4.80
Trytophan	0.19	0.41
Tyrosine	1.20	2.59
Valine	3.24	6.96

TABLE 30
Trash fish species and their frequency of use as feed in marine cage farm in Viet Nam

English name	Scientific name	Usage
Anchovy	*Stolephorus* spp.	Very common
Sardine	*Clupea leiogaster*	Very common
Mackerel	*Scomber* spp.	Very common
Pony fish	*Leiognathus* spp.	Common
Red bigeye	*Priacanthus macracanthus*	Common
Short-body mackerel	*Rastrelliger brachisoma*	Common
Lizard fish	*Saurida* spp.	Common
Rabit fish	*Siganus* spp.	Common
Small squids	*Loligo* spp.	Common
Penaeid shrimp (small)	Penaeidea	Common
Swimming crab (small)	*Portunus* spp.	Common

6.2 Results

6.2.1 Farm by farm growth and feed utilization

The results of the growth and feed utilization trials are presented in Table 31. Across all the farms, the fish that were fed the pellets grew to a higher final weight (i.e. weight at harvest) than those fed trash fish/low-value fish. This difference in growth response was significant in six of the ten farms that cultured snubnose pompano, and at the farm that cultured red snapper (P<0.05). At the farm level, the growth and feed utilization parameters were not analysed statistically. This was due to the low number of replicates (one replicate per treatment per farm), and the concomitant limited analytical power of the statistics.

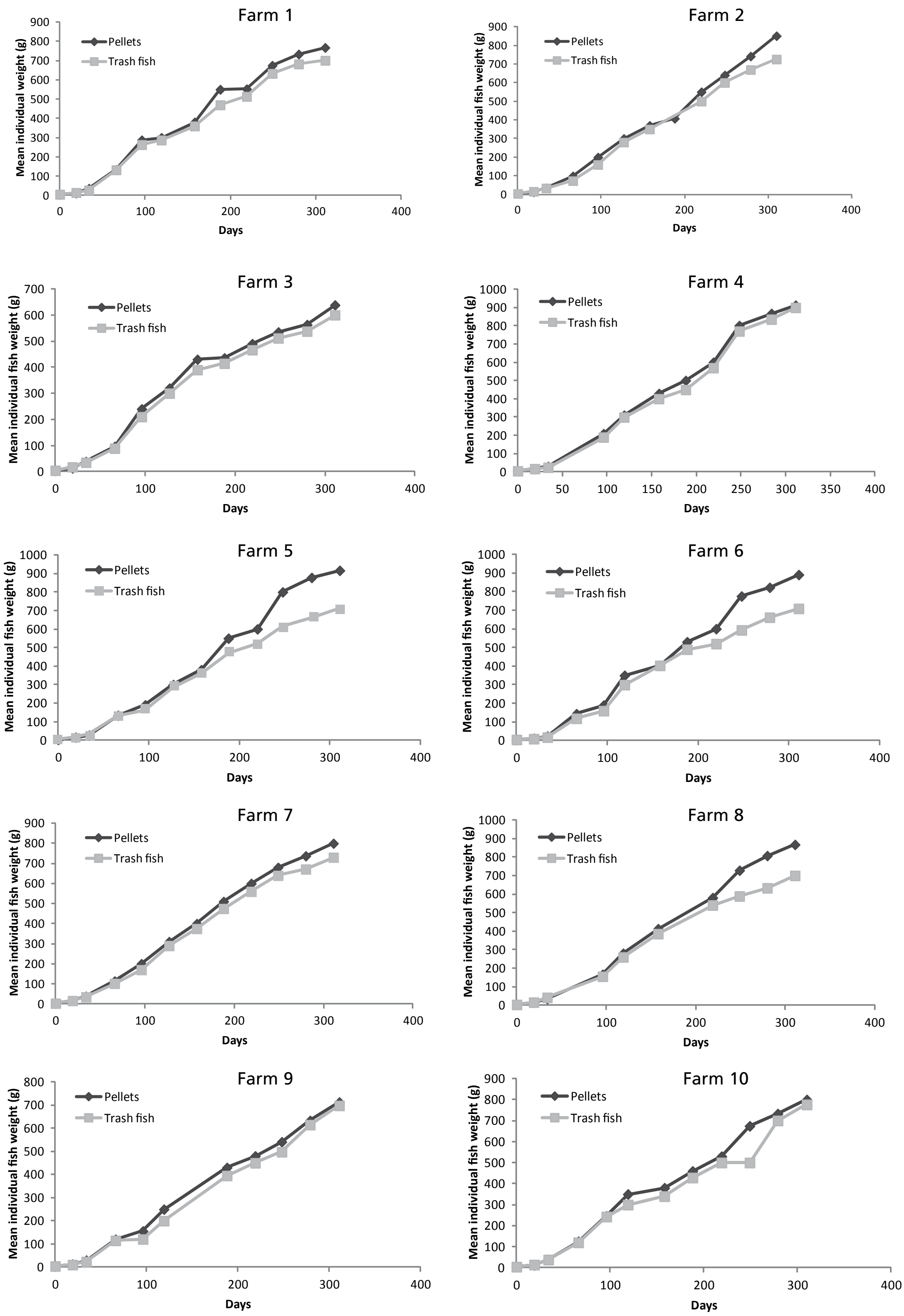
TABLE 31
Farm by farm growth and feed utilization data of snubnose pompano and red snapper in farmers' participatory trial, Viet Nam

Farm Code	Final weight (g)		SGR		FCR		Survival (%)		Total feed fed per cage (kg)	
	Pellet	Trash fish	Pellet	Trash fish	Pellet	Trash fish	Pellet	Trash fish	Pellet	Trash fish
F1-P	767.3 ± 21.6[b]	700.8 ± 18.3[a]	0.96	0.94	3.4	14	92.0	90.0	1 200	4 320
F2-P	850.6 ± 22.3[b]	725.6 ± 8.9[a]	0.97	0.95	2.8	12	78.3	67.5	1 800	5 720
F3-P	638.2 ± 16.4	600.0 ± 22.2	0.92	0.91	3.2	12	80.0	66.8	815	2 450
F3-S	828.8 ± 9.4[b]	771.1 ± 10.2[a]	0.16	0.15	2.2	9	93.2	88.4	450	1 629
F4-P	912.1 ± 17.9	899.4 ± 12.9	0.99	0.99	2.3	10	87.0	88.6	915	3 987
F5-P	916.2 ± 12.8[b]	714.1 ± 14.5[a]	1.00	0.95	2.6	16	75.0	69.3	1 800	8 072
F6-P	890.7 ± 20.3[b]	708.9 ± 6.8[a]	0.99	0.94	2.6	16	78.3	70.2	1 800	8 072
F7-P	799.5 ± 8.5[b]	729.9 ± 11.6[a]	0.49	0.48	2.5	17	90.0	67.7	1 800	8 547
F8-P	867.2 ± 10.9[b]	700.3 ± 9.3[a]	0.98	0.94	3.1	10	75.0	73.4	1 000	2 595
F9-P	712.3 ± 16.0	697.3 ± 14.5	0.95	0.94	3.0	13	80.4	80.0	1 300	5 430
F10-P	799.8 ± 3.7	776.6 ± 12.3	0.97	0.96	3.0	10	66.7	60.0	1 200	3 500

Note: codes F1-P to F10-P denote farms culturing snubnose pompano; code F3-S denotes culturing red snapper. For each farm the mean (±SE) provided. Values in rows with different superscripts are significantly (P<0.05) different.

The specific growth rates recorded for the snubnose pompano ranged between 0.49 and 1.0 for the pellet diet and 0.48 to 0.99 for the trash fish/low-value fish. The SGRs recorded for the red snapper were low at 0.16 and 0.15 for the fish fed the pellets and trash fish/low-value fish respectively. In all cases, the fish fed the pellet feeds recorded slightly higher SGRs, however, due to the lack of replication, the significance of this observation could not be established. The growth of snubnose pompano over the trial period is presented in Figure 6. The fish that were fed the trash fish/low-value fish recorded FCRs that were between 3 and 7 times higher (mean: 4.5) than those fish that were fed the pellet feeds. Survival rates ranged between 60 and 93.2 percent, and were found to be slightly higher in those groups fed the pellet feeds.

FIGURE 6
Mean weight of snubnose pompano fed trash fish/low-value fish or pellets in ten trial farms in Viet Nam



Pellet feed of snubnose pompano in the farmers' participatory trial in Nha Trang Bay, Nha Trang, Viet Nam. Two pellet sizes (3 mm and 5 mm) manufactured and supplied by EWOS, Norway were used for this feeding trial.

Courtesy of FAO/Mohammad Hasan

A cage farmer feeding his fish with poultry feed, Nha Trang, Viet Nam. Cage farmers in Viet Nam often use cheaper feed during the ongrowing phase to reduce the production cost.

Courtesy of FAO/Mohammad Hasan

6.2.2 Growth and feed utilization

The combined growth and feed utilization data from the snubnose pompano trials is presented in Table 32. As there was only one farm culturing red snapper, it was not possible to undertake a statistical analysis of the results. With respect to the snubnose pompano, the analysis revealed that in contrast to feeding the trash fish/low-value fish, feeding pellet feeds resulted in significantly (P<0.05) higher mean weights, and significantly (P<0.05) lower feed conversion ratios (FCR). It was established that while the survival and specific growth rates were also higher in those replicates that were fed the pellet feeds, these differences were not significantly different (P>0.05).

TABLE 32
Overall growth and feed utilization data of snubnose pompano in farmer's participatory trials, Viet Nam

Performance indicator	Snubnose pompano	
	Pellet	Trash fish/low-value fish
Individual fish weight (g)	803.9 ± 8.7b	713.2 ± 6.9a
Survival (%)	80.2 ± 2.4	73.4 ± 3.1
SGR	0.92 ± 0.04	0.90 ± 0.05
FCR	2.84 ± 0.11a	13.0 ± 0.87b
Total biomass increase per cage (kg)	488.5 ± 55.8	388.7 ± 33.9
Total feed fed per cage (kg)	1363.0 ± 127.1a	5267.5 ± 725.4b

Note: For each farm the mean (±SE) given. Values in rows with different superscripts indicate significant differences (P<0.05).

6.2.3 Economic performance

The feed costs associated with the production of one kilogramme of fish are presented in Table 33. An analysis of feed costs for both trial species indicated that the feed cost associated with the production of one kilogramme of fish was higher when pellet feeds were used. Indeed, in terms of feed costs, and in comparison with trash fish/low-value fish it was approximately 41 percent and 72 percent more expensive to use the pellet feeds to produce the snubnose pompano and red snapper respectively.

TABLE 33
Feed cost associated with the production of one kilogramme of fish in farmer's participatory trials, Viet Nam

	Snubnose pompano (*Trachinotus blochii*)		Red snapper (*Lutjanus erythopterus*)	
	Pellets	Trash fish	Pellets	Trash fish
FCR	2.84 ± 0.11[a]	13.0 ± 0.87[b]	2.2	9
Feed cost (US$/kg)	1.75	0.27	1.75	0.27
Feed cost for production (US$/kg fish)	4.97	3.51	4.18	2.43

Note: For each farm the mean (±SE) given. Values in rows with different superscripts indicate significant differences (P<0.05).

6.2.4 Water quality parameters

The water quality parameters that were recorded over the experimental period are presented in Table 34. The type of feed used did not significantly affect the water quality parameters at the culture sites (P>0.05). Nevertheless, there were some differences in the water quality parameters (e.g. ammonia levels) that were recorded at the farms. These differences in water quality were attributed to variations in the hydrographic conditions that were observed at the different culture sites, for example, water depth and current speed. In addition, in some cases, the relative location of trial farms in terms of their proximity to other cage farms was likely to have reduced water currents/circulation, and impacted on the water quality of the surrounding waters. However, it can be concluded that in general, the water quality was suitable for the culture species.

TABLE 34
Summary of the water quality parameters measured in farmers' participatory trial, Viet Nam

Parameter (Mean ± SE)	Snubnose pompano		Red snapper	
	Pellets	Trash fish	Pellets	Trash fish
Salinity (ppt)	33.3 ± 0.1	33.3 ± 0.1	33.1 ± 0.2	33.1 ± 0.2
Secchi depth (cm)	4.74 ± 0.08	4.74 ± 0.08	4.70 ± 0.30	4.70 ± 0.30
DO: cage surface (mg/l)	6.91 ± 0.10	6.89 ± 0.10	7.27 ± 0.27	7.28 ± 0.26
DO: cage bottom (mg/l)	6.68 ± 0.10	6.68 ± 0.11	6.90 ± 0.29	7.11 ± 0.34
DO: outside cages (mg/l)	7.03 ± 0.10	7.04 6 ± 0.10	7.38 ± 0.24	7.35 ± 0.24
pH	8.15 ± 0.01	8.15 ± 0.01	8.21 ± 0.03	8.23 ± 0.03
Temperature (°C)	27.5 ± 0.1	27.5 ± 0.1	27.4 ± 0.4	27.4 ± 0.4
NH_3: inside cage (mg/l)	0.154 ± 0.006	0.154 ± 0.007	0.117 ± 0.015	0.129 ± 0.017
NH_3: outside cage (mg/l)	0.145 ± 0.006	0.149 ± 0.006	0.115 ± 0.015	0.123 ± 0.017

Note: Values in rows with different superscripts indicate significant differences (P<0.05).

6.3 Discussion

6.3.1 Pellet feed quality

Initially, the trial was designed to be undertaken using grouper as the test species. The feed company produced a pellet that they thought would be suitable for grouper. However, as juvenile grouper were not available, the trial species was changed to snubnose pompano and red snapper. As the trial feeds had already been produced, and a change in the feed formulation was not feasible, the trials had to be undertaken using formulations that were designed for grouper.

The species cultured in the Viet Nam trial were snubnose pompano (*Trachinotus blochii*) and red snapper (*Lutjanus erythropterus*). While the dietary requirements for snubnose pompano have yet to be established, the dietary requirements of the closely related Florida pompano (*T. carolinus*) have been reported. Riche (2009) reported the Florida pompano to have a protein requirement of 36 percent and a lipid requirement of 20 percent. In contrast, Lazo, Davis and Arnold (1998) reported a minimum crude protein requirement of 45 percent and a lipid requirement of 8 percent for Florida pompano. In the absence of information pertaining to the dietary requirements of the snubnose pompano, and based on the dietary requirements of closely related species, it is reasonable to suggest that the dietary formulation used in the current trial generally satisfied the gross dietary requirements of the species. However, it is probable that substantial improvements in both feed cost, growth and feed performance could have been made if a diet that was specifically formulated to meet the specific dietary requirements of the species was used.

As outlined in the discussion concerning the use of the formulated pellet feeds in the farmers' trial (Section 3), the dietary requirements for red snapper (*L. erythropterus*) have not been published. As a result, the dietary requirements for a closely related species, the red mangrove snapper (*Lutjanus argentimaculatus*), were used as a proxy for the dietary requirements of the red snapper. These dietary requirements have been cited as 41–43 percent protein, and 9–12 percent lipid (Liao *et al.,* 2008; Catacutan, Pagador and Teshima, 2001). Taking these dietary requirements into consideration, it would appear that the formulations used in this case study were likely to contain a higher level of dietary protein than would be required. To some extent, it is possible that the excess protein in the diet may be limiting to growth as the fish has to expend energy to deaminate the excess protein as opposed to using the energy for somatic growth. However, it is perhaps more likely that the protein was used as an energy source as the fish grew well, and indeed better than those fish that were fed the trash fish/low-value fish. The feed company representative also reported that the diet contained a high level of fishmeal, and thus the diet was likely to be highly digestible and well balanced in terms of the essential amino acid composition.

Preparing trash fish/low-value fish for brown-marbled and humpback groupers, Lampung Bay, Bandar Lampung, Indonesia

Courtesy of FAO/Mohammad Hasan

6.3.2 Farm growth and feed utilization

At a farm level, there was limited replication of the experimental treatments, and therefore it is difficult to make meaningful comparisons between the performances at the different trial farms. Nevertheless, it was evident that performance varied greatly with the FCRs of individual farmers growing snubnose pompano on pellet feeds ranging between 2.3 and 3.4, and those feeding trash fish/low-value fish ranging between 10 and 17. These figures suggest that at some farms, and regardless of feed type, there were substantial feed inefficiencies, and improvements in farming practices could likely result in substantial increases in feed efficiency, profitability and environmental sustainability.

6.3.3 Overall growth and feed utilization

In comparison with the use of trash fish/low-value fish, the superior growth performance that was attained using the pellet feeds attest to their high quality, or the concomitant low quality of the trash fish that has been reported to be of poor quality in Viet Nam. The poor quality of the trash fish is primarily a result of the poor preservation techniques on board ship, especially in the offshore fisheries where vessels may remain at sea for periods of between 1–6 weeks (Edwards, Tuan and Allan, 2004). This is a similar situation to that of China, where the majority of trash fish/low-value fish is derived from the offshore fisheries.

6.3.4 Economic performance

Despite pellet fed red snapper achieving better growth rates than those fed on trash fish/low-value fish, the relatively high cost of the pellet feeds made it more economical to use trash fish/low-value fish. The feed costs associated with production varied between the feed types, with the trash fish/low-value fish costs being substantially lower than those of the pellets. This was especially true for red snapper production, however this assertion is based on results that were not replicated. The price of the pellet feed that was used in the Viet Nam trial was the highest of all feeds used in the country trials. It is anticipated that a lower cost pellet, possibly with lower fishmeal and protein inclusion rates, could be used with similar or better results. In addition, in recent years there has be an increase in the price of trash fish/low-value fish (and fishmeal), suggesting that pellet feeds, and particularly those with low levels of fishmeal, are likely to become increasingly cost competitive.

A survey of marine trash fish/low-value fish and fishmeal use in Viet Nam indicated that in recent years, there has been a significant rise in the use of trash fish/low-value fish in aquaculture, and with the high demand levels from other production sectors such as small-scale pig farming, there appears to have been a doubling of its price. Evidently there is a finite supply of trash fish/low-value fish, and it is unlikely that aquaculture based on the traditional use of trash fish/low-value fish can expand much further than present levels. It was also reported that the majority of the fishmeal that is used in aquaculture formulations in Viet Nam is imported, and while the price of imported fishmeal is increasing, it is favoured over the locally produced fishmeals that are generally of a lower quality (Edwards, Tuan and Allan, 2004). To conclude, it is likely that in the future, formulation costs will increase, and in order to reduce feed costs, there will be drive to use alternative feed ingredients in pellet feeds.

7. SYNTHESIS OF THE FOUR COUNTRY STUDIES

7.1 Limitations on comparisons between four country trials

Where possible, the trials that were undertaken in each country were standardized. The study was based on field trials, and was not intended as a scientific study that would compare the results in the different countries *per se*. Although a similar methodology was applied to all the countries, and the data collection methods were standardized as much

Sampling to monitor the growth of snubnose pompano during the farmers' participatory trial, Nha Trang, Viet Nam.

Courtesy of FAO/Thai Chien

as possible, it was not possible to standardize the culture conditions across the countries. Effectively, each country operated as a separate trial with different commercial feed types and general management strategies being applied; it should also be noted that at a country level, there were differences in the environmental conditions, the farm locations and sites, as well as aspects related to individual farm management. In addition, the species that were cultured varied between countries, and undoubtedly this would have affected the final results, albeit in an unquantifiable manner. Therefore, direct comparisons between the results from each country need to be placed in this context.

7.2 Groupers

An overall summary of the growth, feed utilization and feed cost of production for the grouper species cultured in the trial (China, Indonesia and Thailand) is presented in Table 35. Although two different species of grouper were cultured, and the culture conditions such as stocking size, density, culture period, and the composition of the pellet and trash fish/low-value fish feeds and prices thereof varied between trials, some overall observations can be made, namely, that while there was great variability in the performance parameters within and between countries, the differences between growth rates and survival rates within each country were relatively similar.

TABLE 35
Summary of the growth, feed utilization and feed cost of production of the grouper species fed trash fish/ low-value fish and pellets

	China		Indonesia		Thailand	
Species	**Orange-spotted grouper (*Epinephelus coioides*)**		**Brown-marbled grouper (*Epinephelus fuscoguttatus*)**		**Brown-marbled grouper (*Epinephelus fuscoguttatus*)**	
Performance indicator	**Pellets**	**Trash fish**	**Pellets**	**Trash fish**	**Pellets**	**Trash fish**
Initial weight (g)	28.33 ± 4.41	33.33 ± 7.26	17.2	17.2	40	40
Initial length (cm)	10.57 ± 0.78	11.00 ± 1.00	9.43	9.43	13.4	13.4
Number stocked per cage	1625 ± 625	1625 ± 625	500	500	150	150
Stocking density (fish/m^3)	25 ± 17	25 ± 17	18.5	18.5		
Culture period (days)	196	196	189 - 313	189 - 313	251-254	251-254
Final weight (g)	312.9 ± 24.9[b]	240.3 ± 4.8[a]	400.1 ± 23.3	446.7 ± 15.1	408.8 ± 9.9	417.3 ± 10.0
Final length (cm)	27.7 ± 1.2	27.3 ± 1.5	25.7 ± 0.6	27.3 ± 0.5	25.9 ± 0.2	26.3 ± 0.2
FCR	2.57 ± 0.13	12.33 ± 4.96	2.41 ± 0.21[a]	6.00 ± 0.60[b]	3.09 ± 0.21	13.17 ± 3.97
Survival (%)	36.9 ± 2.8	28.0 ± 0.2	48.6 ± 3.9	49.1 ± 3.4	75.6 ± 3.2	77.9 ± 3.0
SGR	0.38 ± 0.04	0.31 ± 0.06	0.35 ± 0.01	0.37 ± 0.00	0.77 ± 0.03	0.77 ± 0.04
Feed cost (US$/kg)	1.20	0.43	1.35	0.56	1.67	0.40
Feed cost of production (US$/kg fish)	3.08	5.33	3.32	3.40	4.12	4.38

Values with different superscripts are significantly (P<0.05) different.

The survival rates of the trial fish in the different countries were also affected by diseases and disease outbreaks. In most cases the incidence of disease was associated with poor water quality and harmful plankton blooms. Survival rates were the lowest in China, followed by Indonesia, and were highest in Thailand. Survival rates also coincided with the stocking densities used and the farm concentrations in each area, with farms in China being sited at much higher densities than those in Thailand.

Considerable differences were also observed with respect to feed utilization. For example, the FCRs attained using pellets were approximately two and a half in China and Indonesia, but over three in Thailand. With respect to the use of the trash fish/low-value fish, the FCRs that were recorded ranged between 12-13 in China and Thailand, but only six in Indonesia. Even though the FCRs were most likely slightly underestimated in Indonesia - due to the water quality, disease and associated mortality issues that occurred during the initial stages of the trials - the differences between the countries remained large. The higher FCRs attained using the pellet feeds in the trial in Thailand may be attributable to the marine cage farmers' inexperience with the use of pellet feeds that are generally not available to them.

In contrast, in China and Indonesia, pellets are available, and many farmers have previous experience of their use.

Although the environmental conditions would have influenced fish growth, survival and feed performance in the trials, farm management and feeding practices would also have affected the trial results. It has been observed that feeding practices such as feeding frequency (Chua and Teng, 1978) and ration rate (Chua and Teng, 1982) significantly influence performance indices. Feed and feed management practices have been discussed in the case studies, and were shown to vary widely.

7.3 Red snapper

An overall summary of the growth, feed utilization and feed cost of production of red snapper cultured in China and Viet Nam is presented in Table 36. The stocking size, density, culture period, the nutritional composition of pellet and trash fish/low-value fish feeds and the prices thereof varied between the countries, making direct comparisons between the results from each country impracticable. With the exception of the final mean weights of the fish fed the different feed types in Viet Nam, little difference was observed between the growth and feed utilization performance indices. In comparison with the farmers in China where low FCRs were obtained, it appears that the farmers in Viet Nam have considerable room for improvement in their feed management practices.

Between the countries, there were differences in the feed cost of production when pellet feeds or trash fish/low-value fish were used. However, it is important to note that although these costs differed between the countries, this was primarily a result of the prevailing cost of pellets and trash fish/low-value fish in each country, and was not associated with differences in growth performance. Thus, if the feed costs were the same between countries, the trend in economic performance would have also been the same.

TABLE 36
Summary of the growth, feed utilization and feed cost of production of the red snapper fed trash fish/low-value fish and pellets

	China		Viet Nam	
Species	**Red snapper (*Lutjanus erythopterus*)**		**Red snapper (*Lutjanus erythopterus*)**	
Performance indicator	**Pellets**	**Trash fish**	**Pellets**	**Trash fish**
Initial weight (g)	4.54 ± 1.88	4.56 ± 1.88	78.0	78.0
Number stocked per cage	2000 ± 0	2000 ± 0	250	250
Stocking density (fish/m^3)	37 ± 0 (3)	37 ± 0	6.9	6.9
Culture period (days)	182	182	351	351
Final weight (g)	336.0 ± 38.7	365.2 ± 30.8	828.8 ± 9.4[b]	771.1 ± 10.2[a]
FCR	1.31 ± 0.04	5.15 ± 1.04	2.2	9
Survival (%)	71.7 ± 8.2	81.4 ± 4.8	93.2	88.4
SGR	2.45 ± 0.53	2.67 ± 0.75	0.16	0.15
Feed cost (US$/kg)	1.20	0.42	1.75	0.27
Feed cost of production (US$/kg fish)	1.57	2.14	4.18	2.43

Values with different superscripts are significantly ($P<0.05$) different.

7.4 Barramundi and snubnose pompano

A summary of the growth, feed utilization and feed cost of production of barramundi and snubnose pompano cultured in the trials in Thailand and Viet Nam is presented in Table 37. As each species were only cultured in one country, the results of the trials are not comparable between countries. However, in the context of the overall study it is important to note that concomitant with the grouper and red snapper trials, very little difference was observed in terms of the growth and survival rates recorded from those groups fed the different feed types.

TABLE 37

Summary of the growth, feed utilization and feed cost of production of the barramundi and snubnose pompano fed trash fish/low-value fish and pellets

	Thailand		Viet Nam	
Species	Barramundi (*Lates calcarifer*)		Snubnose pompano (*Trachinotus blochii*)	
Performance indicator	**Pellets**	**Trash fish**	**Pellets**	**Trash fish**
Initial weight (g)	33	33	5.3	5.3
Number stocked per cage	150	150	750 ± 75	750 ± 75
Culture period (days)	134-223	134-223	310-614	310-614
Individual fish weight (g)	432.6 ± 7.9	445.6 ± 8.3	803.9 ± 8.7[b]	713.2 ± 6.9[a]
Survival (%)	97.8 ± 0.8	98.4 ± 0.6	80.2 ± 2.4	73.4 ± 3.1
SGR	1.92 ± 0.04	1.94 ± 0.03	0.92 ± 0.04	0.90 ± 0.05
FCR	2.55 ± 0.08[a]	5.51 ± 1.09[b]	2.84 ± 0.11[a]	13.0 ± 0.87[b]
Total biomass increase per cage (kg)	62.3 ± 4.2	65.4 ± 3.4	488.5 ± 55.8	388.7 ± 33.9
Total feed fed per cage (kg)	144.7 ± 10.8[a]	302.8 ± 43.0[b]	1363.0 ± 127.1[a]	5267.5 ± 725.4[b]
Feed cost (US$/kg)	1.67	0.40	1.75	0.27
Feed cost of production (US$/kg fish)	3.07	1.67	4.18	2.43

Values with different superscripts are significantly (P<0.05) different.

7.5 Pellet feeds

In general, little information was available in terms of the nutritional requirements of the culture species, and thus, the pellet feeds could not be specifically formulated to meet the nutritional requirements of the species. However, in general, the pellet feeds appeared to be of moderate to high quality, and the diets contained relatively high levels of crude protein and moderate levels of crude lipid - inclusion rates that are generally required by carnivorous marine fish. With respect to the dietary ash, fibre, calcium and phosphorous levels, all appear to be in the range suitable for the culture of warm water fish (De Silva and Anderson, 1995; NRC, 1983).

7.6 Common themes

The common theme across all of the species and countries is overwhelmingly that, in terms of growth, there is no clear advantage in using either feed type. Although there were instances where one or the other feed types outperformed the other, these instances were a result of feed management practices or possibly the poor quality of the trash fish/low-value fish – notably in China, and possibly Viet Nam. The management practices employed by the farmers were highly variable, not only between the farms but even within each country. Had a controlled experiment using standard methods been applied, a consistent difference between feed types may have been found. However, such a finding would not have proved useful in a commercial setting as management practices play a more important role than feed type. Under such a scenario, the cost or environmental benefits to a particular feed type remain unrealized by the industry.

It has also been suggested that under commercial culture conditions large amounts of feed often remains unconsumed by the target animals, and that feed wastage is more often a result of poor feed management practices than poor feed quality (New, 1996). As opposed to selecting a particular feed type, increased feed efficiencies could be attained by improving feed management practices, and reducing the amount of feed that remains uneaten.

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ANNEXURE A

List of fish species cultured in cages in the Asia-Pacific

Common name	Species	Family/sub-family
Cobia	*Rachycentron canadum* (Linnaeus, 1766)	Rachycentridae
Humpback grouper	*Cromileptes altivelis* (Valenciennes, 1828)	Epinephelinae
Brown-marbled grouper/ tiger grouper	*Epinephelus fuscoguttatus* (Forsskål, 1775)	Epinephelinae
Orange-spotted grouper/ green grouper	*Epinephelus coioides* (Hamilton, 1822)	Epinephelinae
Snubnose pompano	*Trachinotus blochii* (Lacepède, 1801)	Carangidae
Greasy grouper	*Epinephelus tauvina* (Forsskål, 1775)	Epinephelinae
Red snapper/crimson snapper	*Lutjanus erythropterus* (Bloch, 1790)	Lutjaninae
Mangrove red snapper	*Lutjanus argentimaculatus* (Forsskål, 1775)	Lutjaninae
Red seabream	*Pagrus major* (Temminck & Schlegel, 1843)	Sparidae
Camouflage grouper	*Epinephelus polyphekadion* (Bleeker, 1849)	Epinephelinae
Malabar grouper	*Epinephelus malabaricus* (Bloch & Schneider, 1801)	Epinephelinae
Barramundi/Asian seabass	*Lates calcarifer* (Bloch, 1790)	Latidae
Red drum	*Sciaenops ocellatus* (Linnaeus, 1766)	Sciaenidae
Leopard coralgrouper/coral trout grouper	*Plectropomus leopardus* (Lacepède, 1802)	Epinephelinae
Golden trevally	*Gnathanodon speciosus* (Forsskål, 1775)	Carangidae
Giant grouper	*Epinephelus lanceolatus* (Bloch, 1790)	Epinephelinae

ANNEXURE B

Trash fish/low-value species commonly used as feed in cage culture

Common name	Species	Family/sub-family
Torpedo scad	*Megalaspis cordyla* (Linnaeus, 1758)	Carangidae
Japanese scad	*Decapterus maruadsi* (Temminck & Schlegel, 1843)	Carangidae
Yellowstrip scad	*Selaroides leptolepis* (Cuvier, 1833)	Carangidae
Goldstripe sardinella	*Sardinella* spp.	Clupeidae
Indian mackerel	*Rastrelliger* spp.	Scombridae
Anchovy	*Stolephorus* spp.	Engraulidae
Sardine	*Clupea leiogaster*	Clupeidae
Mackerel	*Scomber* spp	Scombridae
Pony fish	*Leiognathus* spp	Leiognathidae
Red bigeye	*Priacanthus macracanthus*	Priacanthidae
Short-body mackerel	*Rastrelliger brachysoma*	Scombridae
Lizard fish	*Saurida* spp.	Synodontidae
Rabit fish	*Siganus* spp.	Siganidae
Small squids	*Loligo* spp.	
Penaeid shrimp (small)	Penaeidea	Penaeidea
Swimming crab (small)	*Portunus* spp.	
Silver conger eel	*Muraenesox cinereus*	Muraenesocidae
Giant sea pike	*Shyraena jello*	Sphyraenidae
Goat fish	*Upeneus spp*	Mullidae
Scad	*Decapterus* spp.	Carangidae
Black pomfret	*Parastromateus niger*	Carangidae
Indian pomfret	*Psenes indicus*	Ariommatidae

ANNEX 2

Comparison of the environmental impact between fish fed trash fish/ low-value fish and pellet[1]

EXECUTIVE SUMMARY

The project TCP/RAS/3203 "Reducing the dependence on the utilization of trash fish/ low-value fish as an aquaculture feed for marine finfish in the Asian region" involved assessing and comparing the environmental impacts between fish fed pellet or trash fish/low-value fish in trial cage farms across four countries.

Baseline data comprising position, currents and bathymetry were collected from the trial cage farms. Current speed, direction and dispersion data indicate water exchange and mixing at the cages, and represent important factors influencing environmental impacts and production carrying capacities. Water samples were collected on fortnightly/ monthly basis from inside and outside the cages, and used to compare water quality between fish fed pellets and trash fish/low-value fish. Sediment quality beneath and close to the cages was assessed for organic loading. A test was made to determine the level of overfeeding by the farmers in Viet Nam and Thailand. A series of experiments were undertaken to assess the risk of bacterial pathogen transfer to the cultured fish from feeding trash fish, and the scale of nutrient leaching from trash fish/low-value fish that was stored and then fed after a number of days. Comparative estimates were made of the energy use between the fishing for trash fish and the manufacture of the pelleted feeds. In addition, an estimate was made of the difference between the fish-in fish-out (FIFO) ratios derived from feeding either pellets or trash fish.

The results of the study demonstrated that irrespective of culture species, there was no significant difference in the environmental impacts associated with feeding fish either trash fish/low-value fish or 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. Finally, in contrast to feeding trash fish/low-value fish, higher levels of nutrient leaching into the water column were observed from the use of pellet feeds.

The study also revealed that 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 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 may have been due to the low stocking densities used in the farm trials. Higher stocking densities and corresponding input levels would likely have led to different results. This conclusion was accepted by the stakeholders at the farmer workshops, and affirms the significance of control measures such as limiting farm numbers, and fish and feed inputs to ensure that effluent loads remain within the assimilative capacity of the environment. Zoning can be applied to limit the number of farms in a culture area to an optimal density, and better environmental management can be achieved by optimising

[1] This report has been prepared by Patrick White, FAO Consultant to the project.

stocking densities and improving feed management practices. Finally, 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.

1. INTRODUCTION

The project TCP/RAS/3203 (D) "Reducing the dependence on the utilization of trash fish/low-value fish as feed for aquaculture of marine finfish in the Asian region" is a Technical Cooperation Programme of the Food and Agriculture Organization (FAO) and was coordinated by the Network of Aquaculture Centres in Asia-Pacific (NACA). The project inception workshop was held in September 2008, and involved case studies in 4 countries (China, Indonesia, Thailand and Viet Nam).

The production of high value marine fish in the Asia-Pacific region is dependent on the use of trash fish/low-value fish. As a result of the high food conversion ratios associated with the use of these fish as a feed, the practice remains a contentious issue from both resource use and environmental integrity perspectives.

The continued growth of this sub-sector in the Asia-Pacific region will likely depend on a shift from the direct use of trash/low-value feedfish to formulated feeds. Using case studies based on small-scale farmers in the four countries, the study compared production, economic and environmental differences between different culture practices and finfish species.

2. ENVIRONMENTAL IMPACT

Feed type, quality and feeding strategy have major influences on the environmental impacts between shore-based and open water farming systems. Excess nutrients that are not utilised by the culture fish or shrimp are released into the environment where they accumulate. 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. In freshwater bodies, phosphorus is typically the limiting nutrient (Hudson, Taylor and Schindler, 2000), and thus its addition will dictate the amount of primary production (algal growth). In marine environments, nitrogen is typically the limiting nutrient (Howarth and Marino, 2006), and thus its addition will also dictate primary production.

The excess nutrients are released into the environment in two forms - dissolved and particulate.

Dissolved nutrients

Soluble nutrients derived from the digestion processes of farmed animals dissolve in the water column, and their dilution and transport is a function of water current dynamics. Typically, dissolved nutrients are quickly dispersed and utilised by bacteria, phytoplankton and zooplankton. However, under certain hydrodynamic conditions, high levels of nutrients released on a continuous basis can lead to eutrophication and/or algal blooms.

Eutrophication, low oxygen events, and fish kills affecting local fisheries and fish cage production systems are common events in some lakes and reservoirs in Asia. These events can occur when there is a high density of small scale fish cage farms that together produce volumes of excess nutrients in dissolved and particulate forms that are beyond the carrying capacity of the water bodies (Abery *et al.*, 2005).

According to Olsen *et al.* (2006), 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 and phosphorus in freshwater systems and in some marine seas such as the Mediterranean.
- The local hydrodynamic conditions and the depth of the cage sites.

- The degree of exposure of bays and the near-shore coastal areas in terms of water circulation.
- The stocking density of the fish and the feed conversion ratios (FCR) attained at a local scale, and at a regional scale, the density of the fish farms.

Of these, the hydrodynamics of the system is the most important factor affecting the impacts of the nutrients on the water column. At the local level, a large farm (or a large number of small farms) located in an enclosed water body would have a higher impact on the environment than the same farms being located in more open sites that are exposed to more dynamic hydrodynamic conditions. The impact of the latter would be less severe but more prevalent i.e. the impacts would be spread over a wider area.

Excess inorganic nitrogen and phosphorus derived from fish cages is available immediately for phytoplankton uptake. Sites with low flushing will exhibit increased phytoplankton biomass with peak soluble nutrient loadings occurring during those periods of highest feed input.

Sedimented nutrients

Solid wastes comprising uneaten feed pellets, feed fines (fine particulates caused by poor feed manufacture, pellet damage during transport, or by using automatic feeding systems), and faecal material can accumulate beneath production cages and in the outflows of aquaculture facilities. Particulate nutrients settle and are assimilated by sediment benthos flora and fauna. If particulate nutrients are released in excess of the assimilation capacity, they build up and alter the biodiversity of the area. In extreme cases, the accumulation of nutrients can cause anoxic conditions, kill benthic organisms in the sediment, and smother nearby sea grasses and corals. The accumulation of the nutrients in the sediments depends on the local currents and depth.

Organic sediments can impact sensitive benthic habitats (e.g. sea grasses, corals) close to the farm (Holmer *et al.*, 2008), and these may be important as a food source or habitat for fish.

A high FCR suggests that the fish are using relatively low levels of the dietary nutrients for somatic growth. The unassimilated nutrients will be released into the environment. Improvements in the FCR reduce the level of nutrients released to the environment, and thus reduce the impacts of the farming operation. A reduction in feed losses and improvements in nutrient conversion efficiency would improve FCR. But FCR is also affected by water temperature, fish size and fish status, most notably health.

3. METHODOLOGY AND FINDINGS

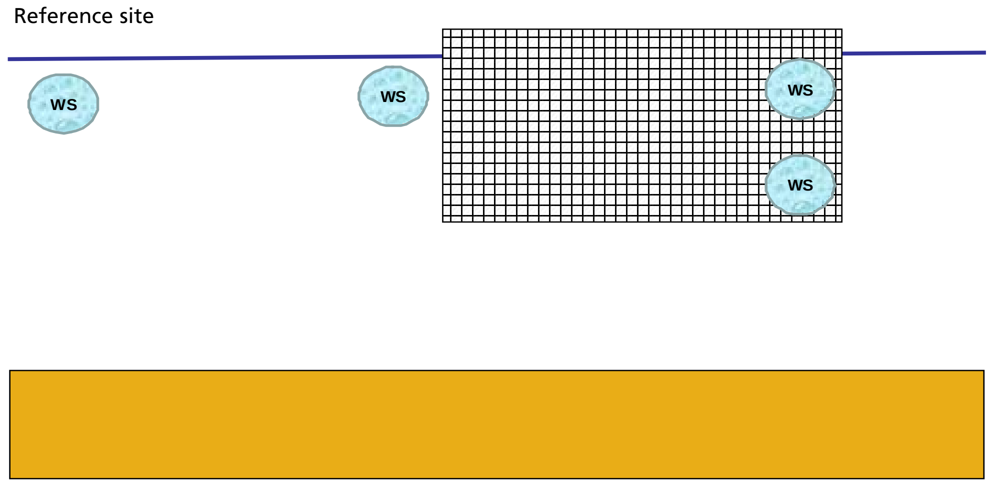
Routine water quality parameters were monitored at each of the farm sites, however the parameters that were monitored varied between the trial countries. The details of the water quality monitoring protocols that were adopted in the trial countries, and the results thereof, are provided in Annexure 1. However, as a guide the following parameters were recorded:

- Temperature
- pH
- Salinity
- Turbidity (Secchi disk – depth)
- Dissolved oxygen
- Ammonia

In some cases, additional parameters were collected and analysed. These included:

- Nitrite
- Nitrate
- Phyto- and zooplankton.

FIGURE 1
Water quality sample locations



Each parameter was measured both inside and outside the cages, and control samples were collected from un-impacted reference locations during the latter part of the data collection process (Figure 1).

In addition to the regular fortnightly/monthly sampling, an additional survey was carried out to establish:

- Bathymetry
- Sediment characteristics – benthic fauna and qualitative characteristics using mini corer and grab samples
- Current speeds and direction (drogues)
- Current dispersion (drogues)
- Bacterial analysis (total bacterial counts)
- GIS mapping of the project cages and drogue dispersion

The above data collection was carried out from selected trial cage farms in Nha Trang, Viet Nam (10 farms), Phuket, Thailand (5 farms) and Bandar Lampung, Indonesia (5 farms).

3.1 GIS mapping of the project cages

Cages were mapped using a GPS (Garmin Oregon 300), and readings were taken at the corners of each farm using the format N DD° MM.MMM' E DDD° MM.MMM' (degrees and decimal minutes). While the farms in Viet Nam were clustered in one area, the farms in Indonesia and Thailand were distributed across a number of locations (Figure 2).

3.2 Current speed, direction and dispersion

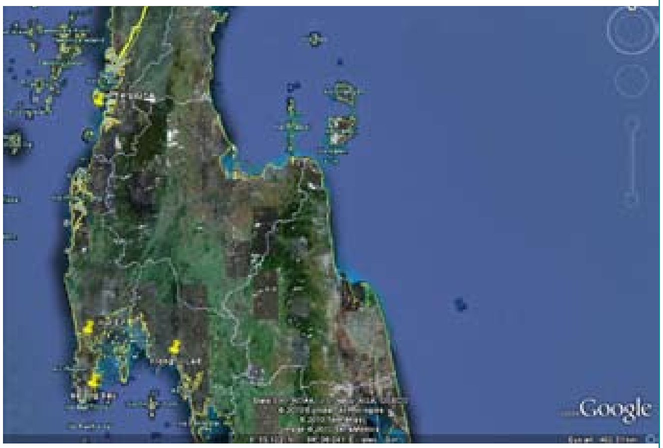
Under cage culture conditions, water exchange is one of the most important factors influencing environmental impacts and production carrying capacities. In order to assess water exchange and mixing at the cage sites, current speed, direction and dispersion were measured.

Current direction

The current direction was determined using drogues (Figure 3). In deep water areas (greater than 10 metres), the drogues were deployed at a depth of 5 metres, and in the shallower areas (below 5 metres), they were deployed at 2 metres. The drogues were released for a period of between 20 and 40 minutes, and their location was regularly mapped using GIS. Eight drogues were released simultaneously, and the increase in surface area coverage (dispersal) was assessed at regular intervals.

FIGURE 2
The location of the cage farms included in the study

Cage sites in Viet Nam



Cage farm sites in Thailand

Cage farm sites in Indonesia

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, the water flow was significantly faster at 38 cm/sec (Table 1).

FIGURE 3
Drogues used for the measurement of current dispersion

Drogue design

Deployed drogues

TABLE 1
Current speed and direction at the cage sites

Date	Place	Average current speed (cm/sec)	Current speed range (cm/sec)
11/01/2010	Viet Nam	2.2	1.7 – 2.6
15/01/2010	Thailand - Phuket	4.6	2.2 – 7.7
16/01/2010	Thailand – Krabi estuary	38.3	26.7 – 56.5
20/01/2010	Indonesia - Tanjung	5.9	2.2 – 9.6
20/01/2010	Indonesia - Pukawan	4.0	3.7 – 4.3
20/01/2010	Indonesia - Mitam	4.7	4.7 – 4.8
21/01/2010	Indonesia – Ringang	5.5	

Current dispersion

Current dispersion is a measure of the mixing of the water column and an indicator of the degree to which nutrients derived from a fish farm are diluted in the receiving water body. Dispersion rates ranged from zero at one site in Indonesia to 33.8 percent per minute in Thailand (Table 2). The estuarine site in Thailand that recorded the highest current speeds also recorded the highest dispersion rate at 1 985 percent per minute.

TABLE 2
Water current dispersion rates in the project area

Date	Country	Average dispersion (percent/min)	Dispersion range (percent/min)
11/01/2010	Viet Nam	11.9	6.5 – 24.8
15/01/2010	Thailand - Phuket	33.9	31 – 36.7
16/01/2010	Thailand - Krabi	1 985	750 – 3 680
20/01/2010	Indonesia - Tanjung	5.4	3.3 – 7.5
21/01/2010	Indonesia - Ringang	0.0	–
21/01/2010	Indonesia - Mitam	16.7	5.0 – 28.3
21/01/2010	Indonesia - Puhawang	5.0	0 – 10.0

3.3 Bathymetry

Water depth (bathymetry) was established using a hand held echo sounder (Plastimo Echotest II) at the corner of project farms, reference sample sites, and the location points of the drogue readings.

The water depth varied between 3 – 5 metres at the estuarine site in Thailand, and between 8 and 25 m in the open sea sites (Table 3).

TABLE 3
Water depth at the cage sites

Country	Water depth (metres)
Viet Nam	12 – 25
Thailand - Phuket	12 – 20
Thailand - Krabi	3 – 5
Indonesia - Tanjung	5 – 22
Indonesia - Ringang	10 - 15
Indonesia - Mitam	8 – 12
Indonesia - Puhawang	14 – 15

3.4 Water quality

Water quality is influenced by a number of factors including the current velocity at the time of sampling, and the time that has elapsed between the feeding of the fish and the collection of the samples. As a result, nutrient loadings vary, and while the impact is usually short term - as algae and plankton quickly assimilate the nutrients - poor water exchange characteristics in the vicinity of the farms can lead to eutrophication.

As the trial cages (fed with pellets and trash fish) were located among other cages whose operators were using both pellets and trash fish, it was not possible to distinguish the environmental impacts between the fish fed exclusively with pellets or trash fish. As a result, the impacts measured are qualitative and should be used to provide an indication of the impacts between a number of cages fed a combination of pellets and trash fish.

Water quality was similar across all of the case studies, and there was very little difference in the water quality between:

- Inside and outside of the cages
- Between the top and bottom of the cages
- Between cages that were fed pelleted feeds or trash fish
- Cages that were used to culture different species

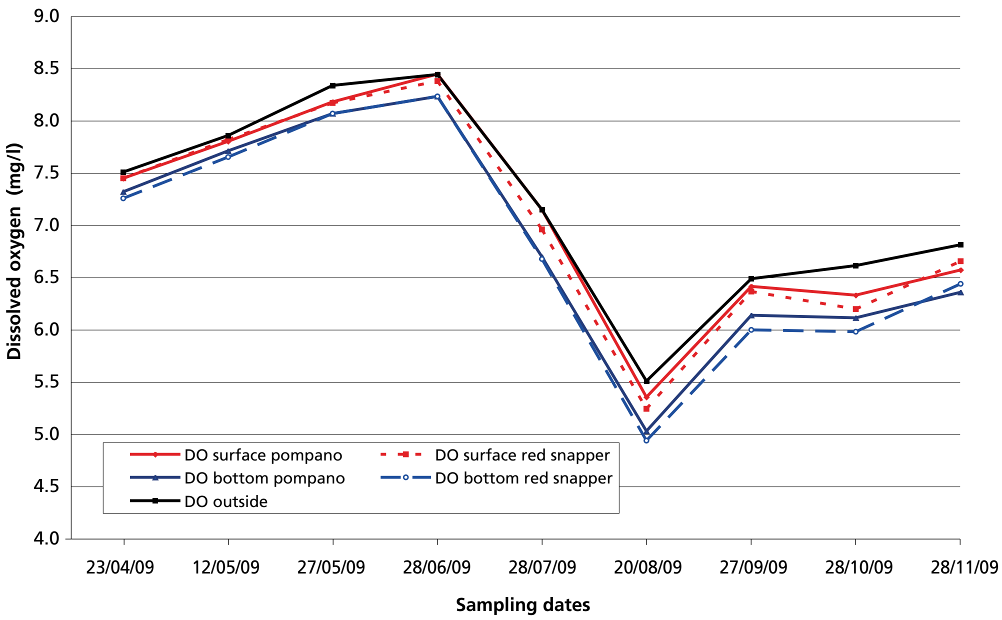
Nevertheless, with respect to ambient water quality conditions and the increasing biomass of fish within the cages, water quality was found to differ over the culture period.

Dissolved oxygen

In Viet Nam, the dissolved oxygen concentrations did not differ significantly between the samples collected from the surface, bottom or outside of the cages, or between the samples collected in the cages culturing snubnose pompano or red snapper. However, dissolved oxygen levels did differ during the culture period, decreasing rapidly between June and August (Figure 4).

FIGURE 4

Dissolved oxygen levels inside and outside the snubnose pompano or red snapper cages in Viet Nam fed trash fish and pellet

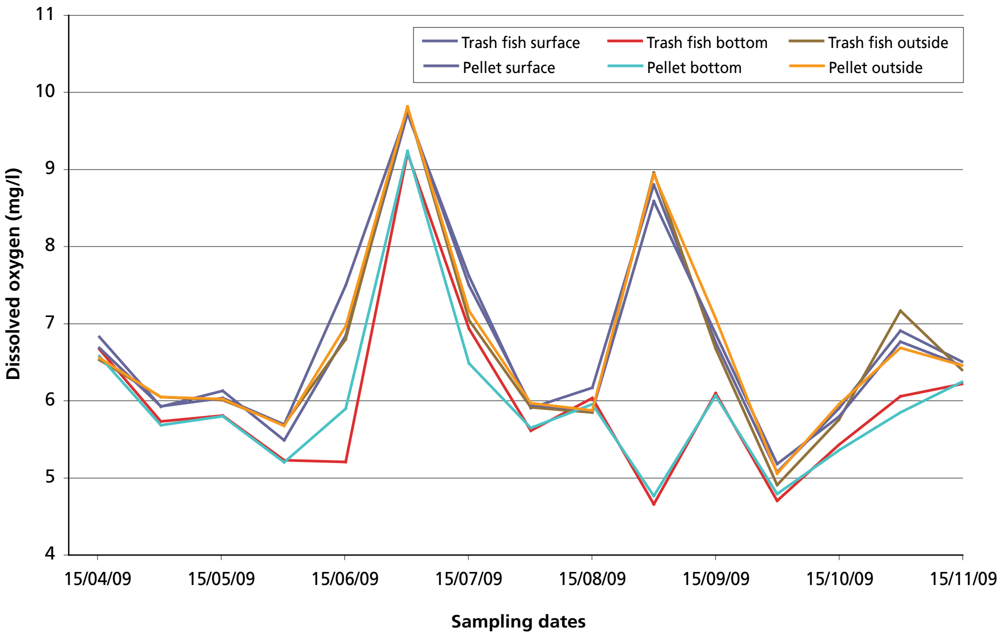


In China, the dissolved oxygen concentrations did not differ significantly between the samples collected from the surface, bottom or the surface waters outside of the cages, or between the samples collected in the cages culturing green grouper or red snapper. However, dissolved oxygen levels differed during the culture period, increasing rapidly between June and October (Figures 5 and 6).

Similar results were observed in the dissolved oxygen levels when grouper and barramundi were cultured in Thailand. In these cases, the concentrations of dissolved oxygen did not differ significantly between the samples collected from the surface, bottom or the surface waters outside of the cages (Figures 7 and 8).

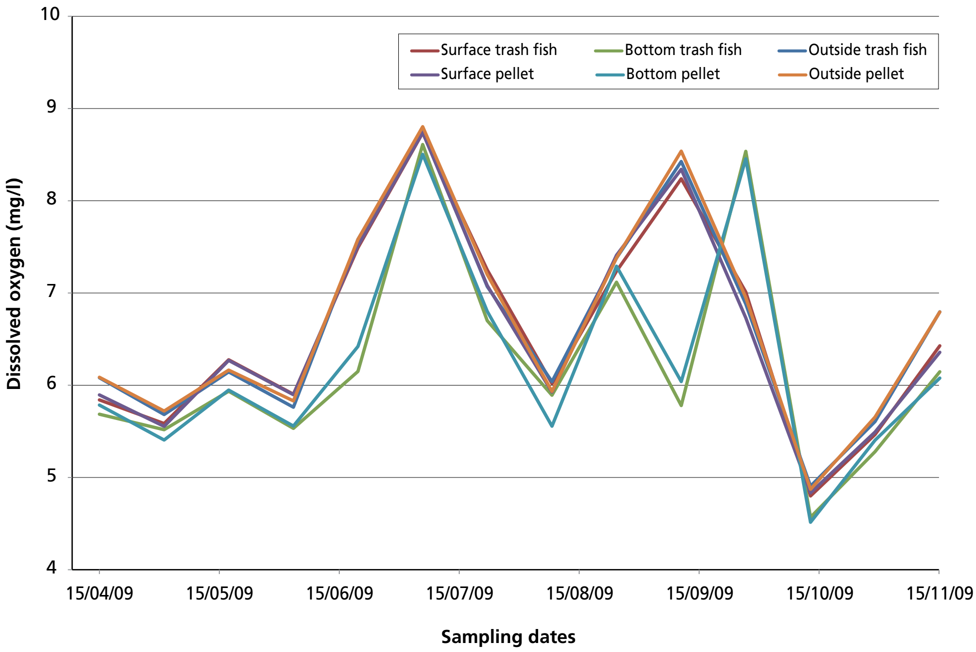
In Indonesia, dissolved oxygen levels were only measured at the farm level as shown by the farmer's name (e.g., Bobby, Parmato, Robby, Alung, Atiek and Sitepu). While there were significant variations in the dissolved oxygen levels between different farms, the differences were attributed to the farms being located in different areas of the bay (Figure 9).

FIGURE 5
Dissolved oxygen levels inside and outside the orange-spotted grouper cages in China



Note: Water quality data in China were collected every fifteen days from April to November 2009.

FIGURE 6
Dissolved oxygen levels inside and outside the red snapper cages in China



pH

In Viet Nam, the pH concentrations of the samples did not differ significantly between those collected in the cages culturing either pompano or red snapper. However, the pH differed during the culture period, increasing between April and August and decreasing slightly between September and November (Figure 10).

In China, the pH concentrations did not differ significantly between those samples collected in the cages culturing orange-spotted grouper or red snapper - the exception

FIGURE 7
Dissolved oxygen levels inside (surface and bottom) and outside (surface) the brown-marbled grouper cages in Thailand

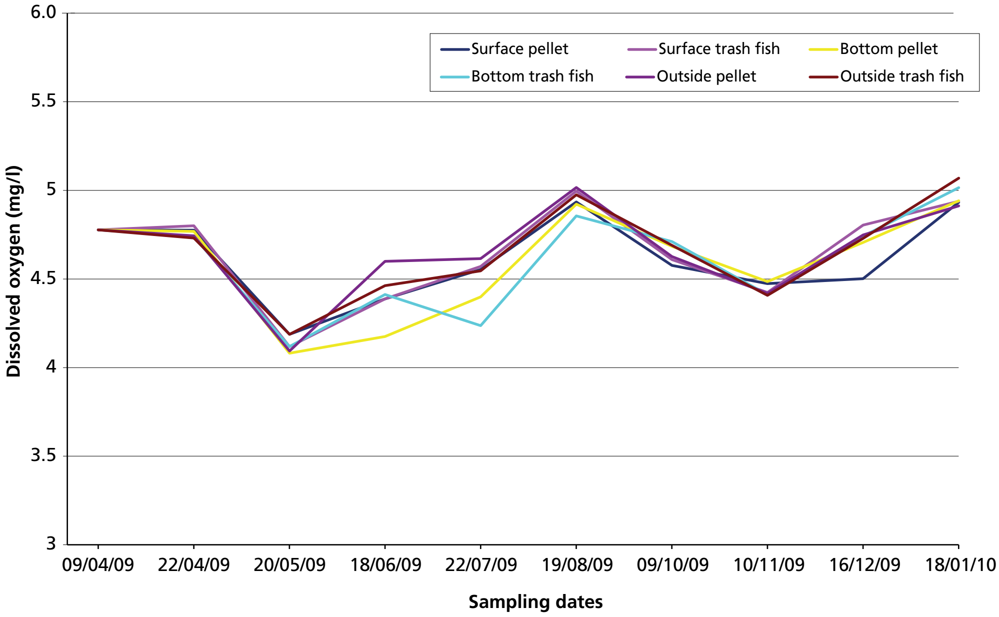
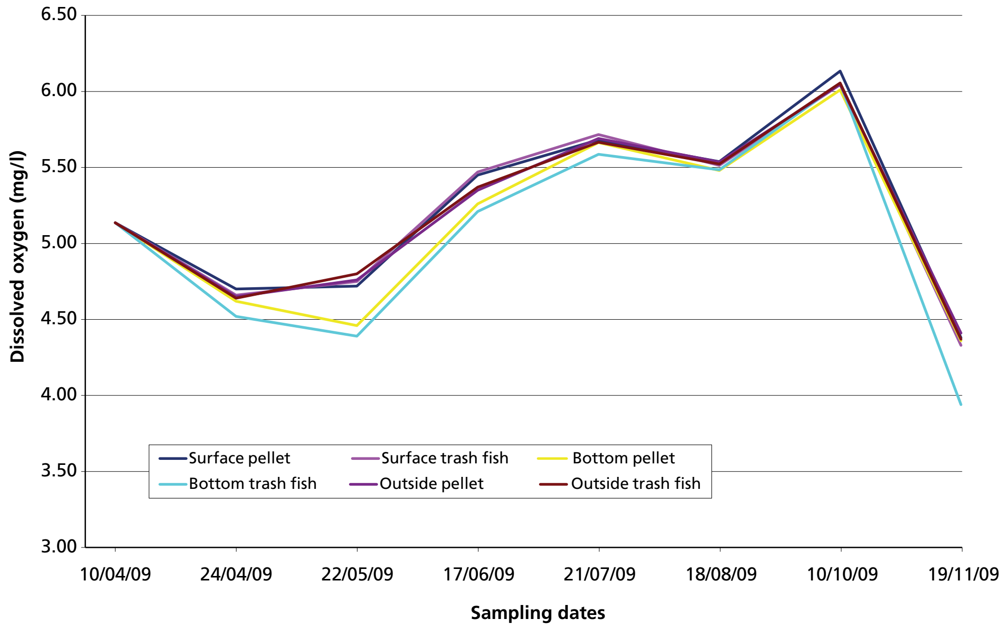


FIGURE 8
Dissolved oxygen levels inside (surface and bottom) and outside (surface) the barramundi cages in Thailand



being the penultimate three sampling periods. The reason why significant differences were observed at these sampling periods could not be established. Nevertheless, the pH did differ during the culture period, decreasing towards the end of the trial (Figure 11).

In Indonesia, pH measurements were only undertaken at the farm level. The pH over the experimental period was relatively constant, and ranged between 7.8 and 8.3. These pH levels are well within the recommended levels of 7 and 8.5 (Figure 12).

FIGURE 9
Dissolved oxygen levels at different farms in Indonesia

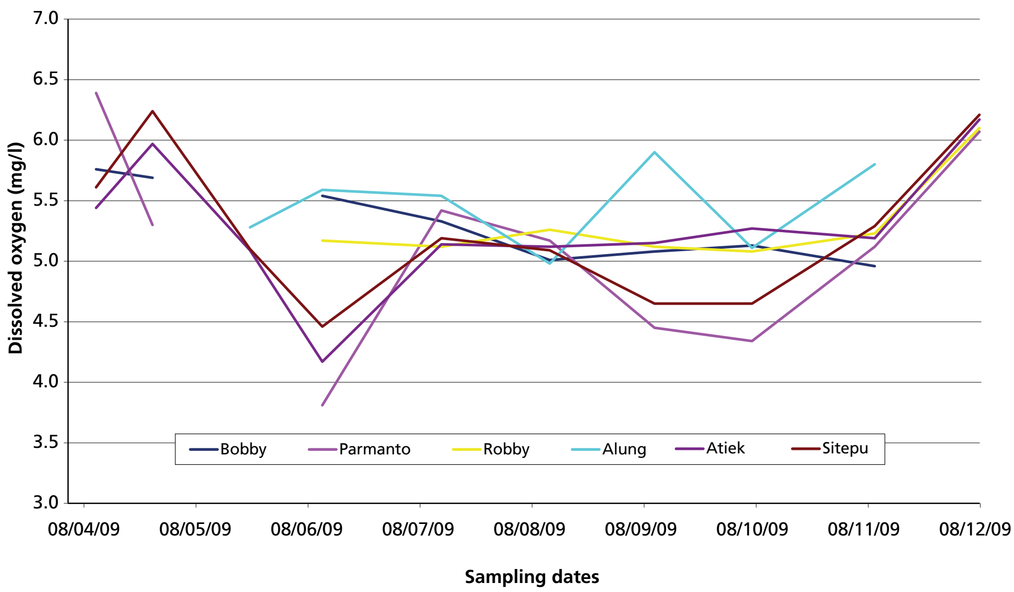
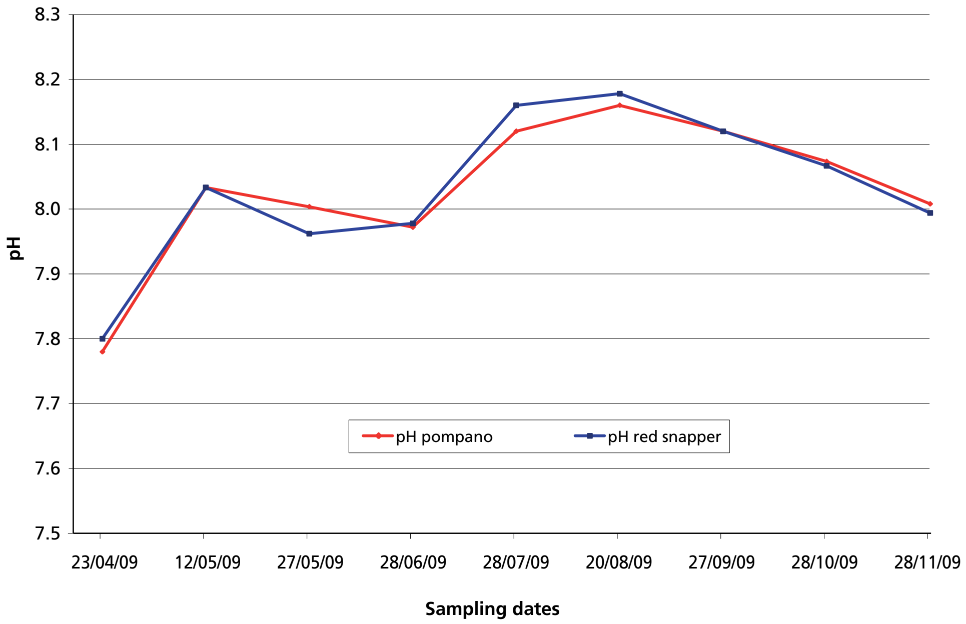


FIGURE 10
pH levels inside the snubnose pompano and red snapper cages in Viet Nam fed trash fish and pellet



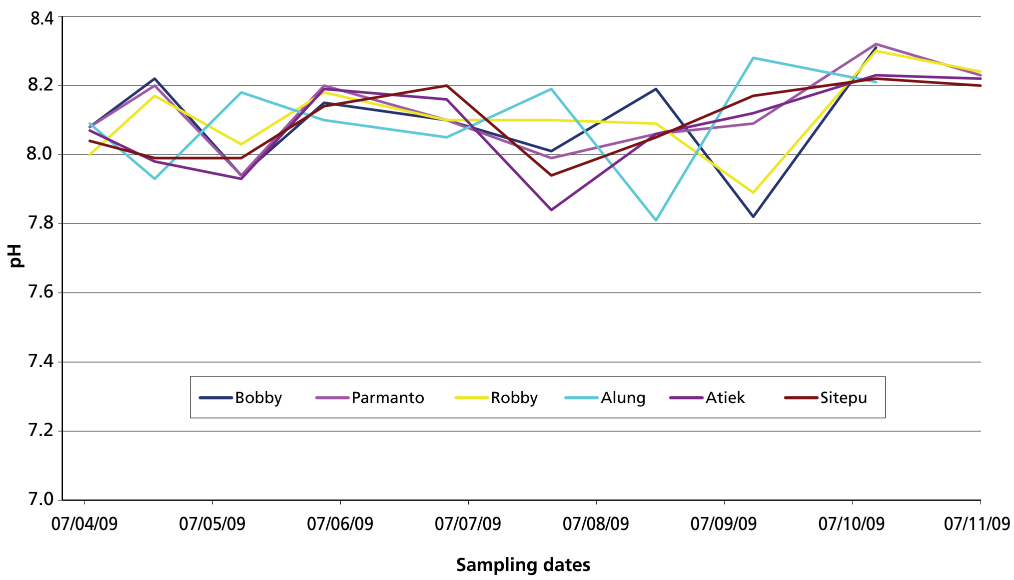
Ammonia (NH_3)

In Viet Nam, the ammonia concentrations recorded inside and outside the cages differed significantly between those samples collected in the cages culturing red snapper and snubnose pompano. A significant increase in the ammonia concentrations was recorded during the last three months of the trial. These increases may be attributable to an increase in biomass, and the increased quantity of feed fed to the fish (Figure 13).

In Thailand, the ammonia concentrations differed in the tiger grouper and barramundi cages (Figures 14 and 15). In the barramundi cages, there was an increase

FIGURE 11
pH levels inside the orange-spotted grouper and red snapper cages in China

FIGURE 12
pH levels at different farms in Indonesia



in ammonia concentration prior to harvest, however this increase was not observed in the tiger grouper cages. The ammonia concentrations did not significantly differ between the inside and the outside of the cages of the fish fed either the pellet or trash fish diets.

In Indonesia, the ammonia measurements were undertaken at the farm level. Ammonia concentrations peaked during September and October 2010 (Figure 16), when in some cages, the concentrations exceeded the maximum recommended levels (Table 4). These levels were significantly higher than those recorded in the other study

FIGURE 13
Ammonia levels inside the snubnose pompano and red snapper cages in Viet Nam fed trash fish and pellet

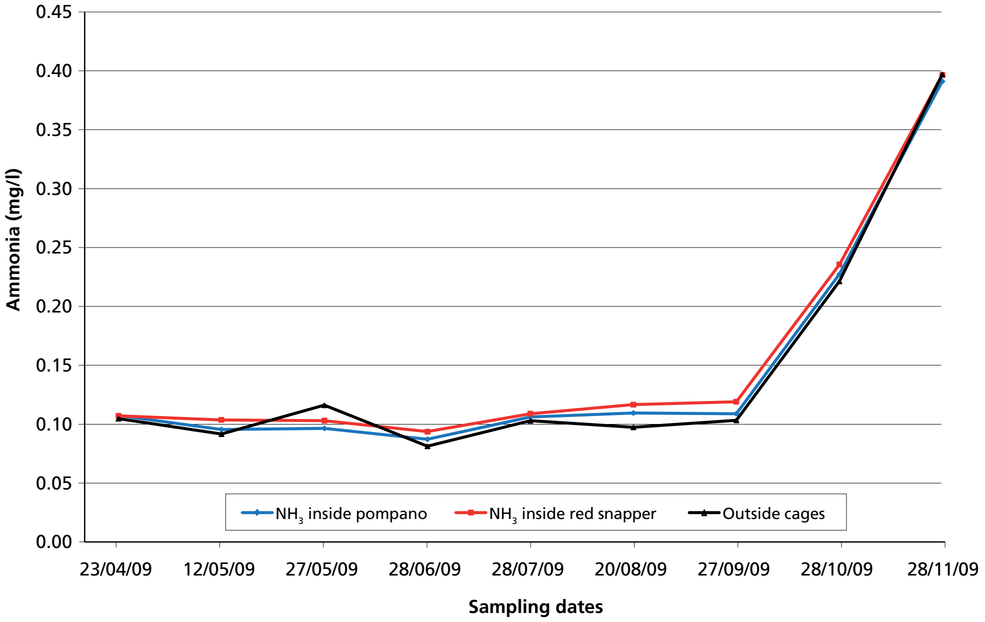


FIGURE 14
Ammonia levels inside (surface and bottom) and outside the barramundi cages in Thailand

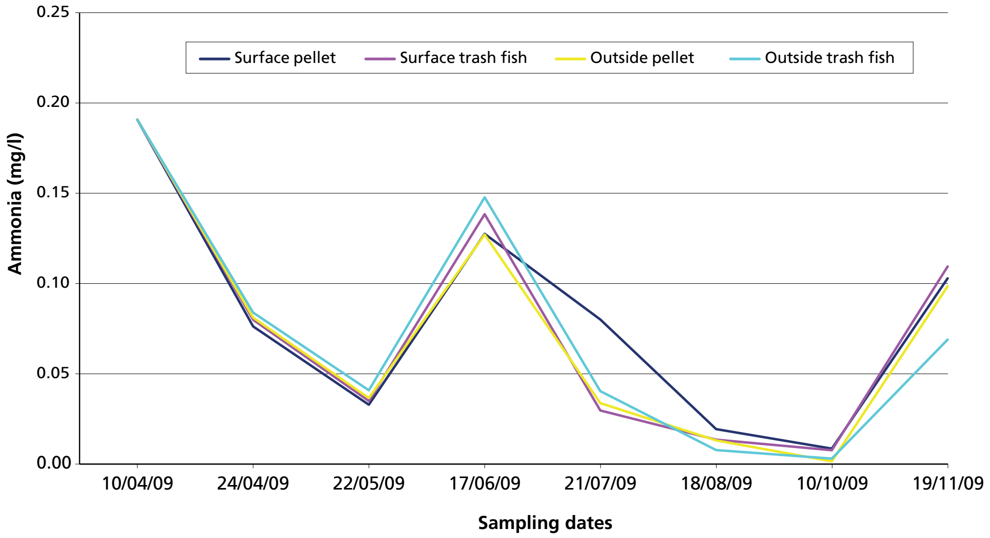


TABLE 4
The maximum recommended water quality levels in Indonesia

Parameters	Unit	Acceptable range
pH	-	7.0 – 8.5
Dissolved Oxygen (DO)	mg/l	>4
Nitrite (NO_2)	mg/l	0.05
Nitrate (NO_3)	mg/l	0.008
Ammonia (NH_3)	mg/l	0.3
Phosphate (PO_4)	mg/l	0.015
Total organic matter	mg/l	P <50

countries. The reason why this should have been the case could not be established.

In Indonesia, additional water quality parameters were measured. These included the concentration of nitrate, nitrite and phosphate inside the cages. It was established that while the water quality changed over time, and with the exception of the Alung farm, which was located close to the outlets of a large number of shrimp farms, there were no significant differences between the water quality recorded on the farms (Figures 17, 18 and 19).

FIGURE 15
Ammonia levels inside (surface and bottom) and outside the brown-marbled grouper cages in Thailand

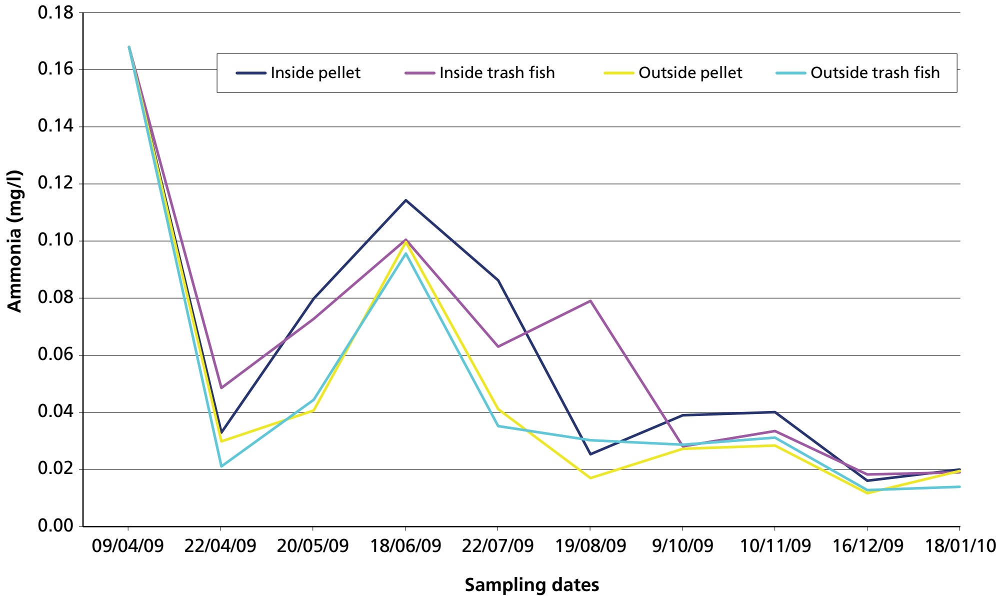
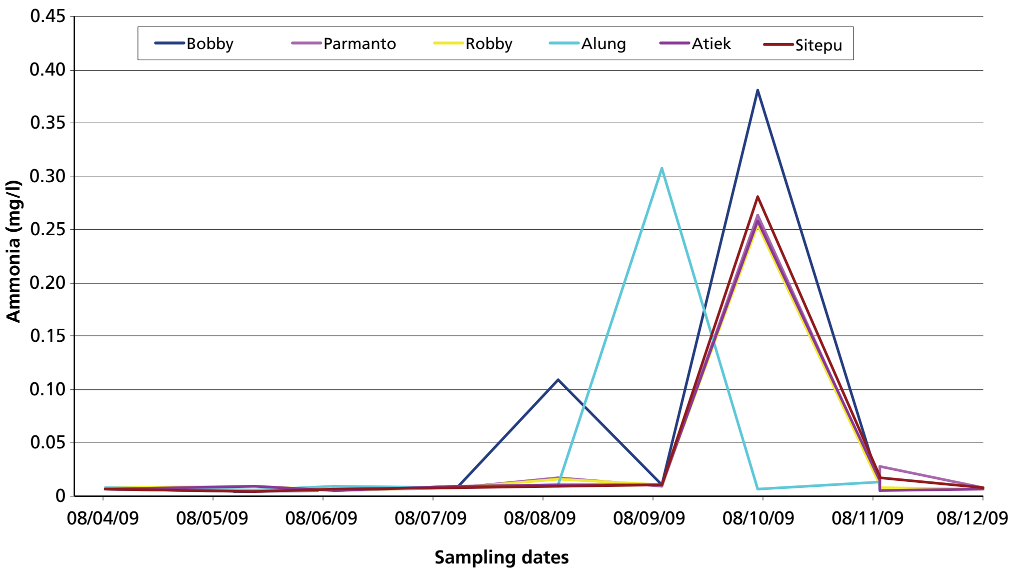


FIGURE 16
Ammonia levels at different farms in Indonesia



The data sets from each of the country trials were tested for normality to ensure that the data followed a Gaussian distribution, and for homogeneity. If both assumptions were met for the water quality variables of interest, a statistical analysis was undertaken using Levene's Test for Homogeneity of Variance, and ANOVA of Squared Deviations from Group Means.

The significant differences ($P<0.05$) between the country trials were as follows:

- **Viet Nam -** The two culture species (red snapper and snubnose pompano) differed only with respect to levels of ammonia recorded inside and outside the cages. These increases may be attributable to an increase in biomass and the increased quantity of feed fed to the fish.

FIGURE 17
Nitrate levels at different farms in Indonesia

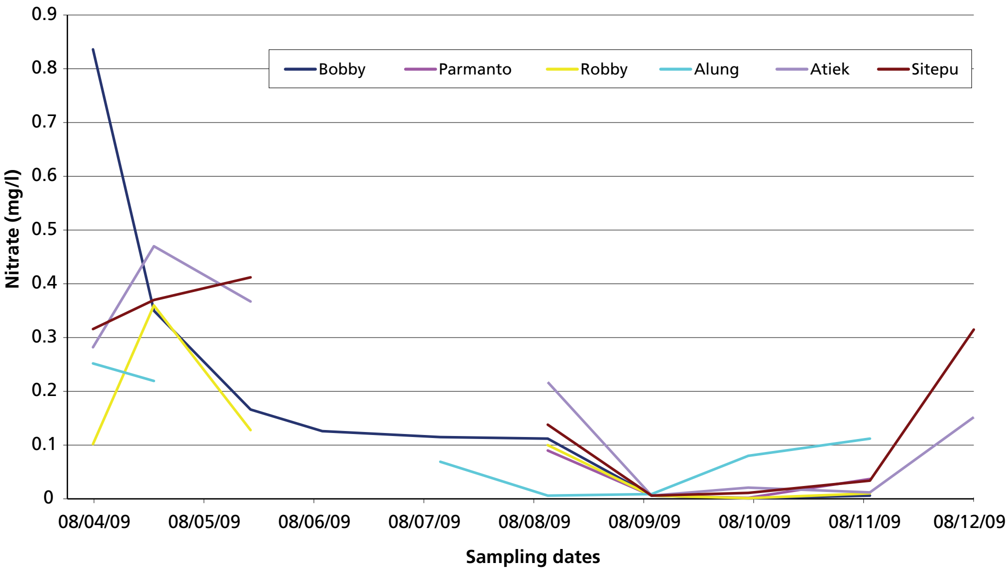
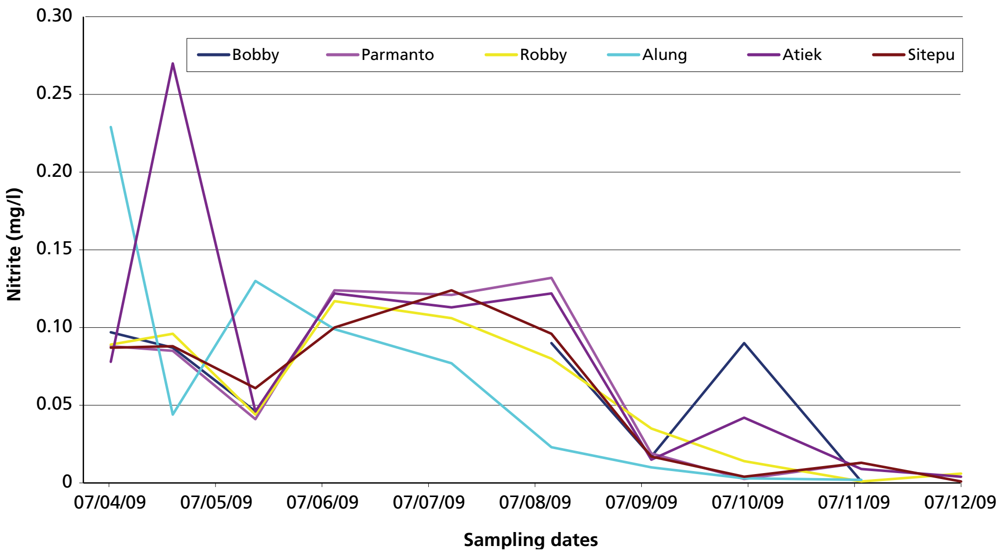


FIGURE 18
Nitrite levels at different farms in Indonesia

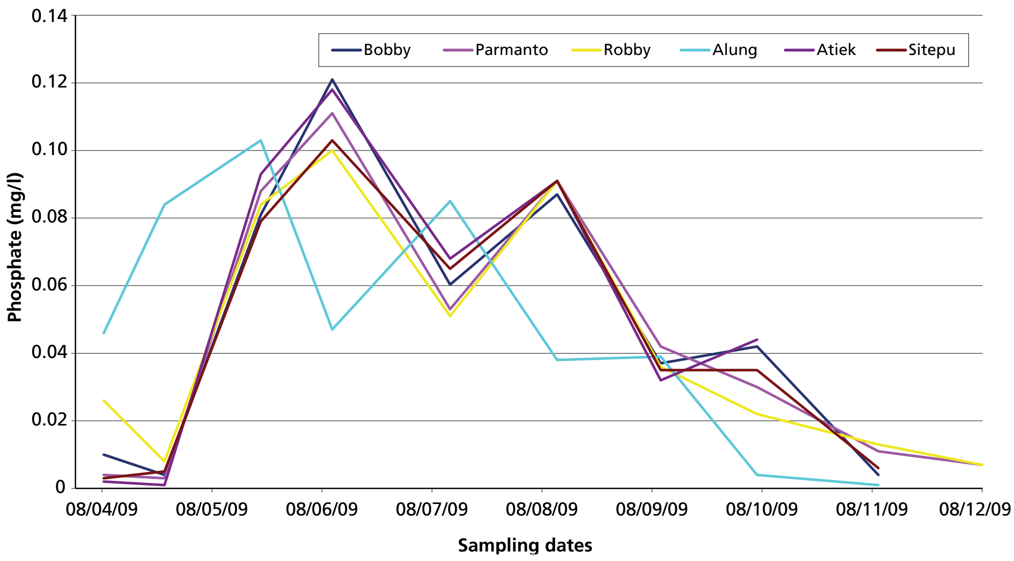


- **Thailand** - None of the water quality parameters differed significantly with feed types or species.
- **China** - None of the water quality parameters differed significantly with feed types.
- **Indonesia** - None of the water quality parameters differed significantly with feed types, the exception being the significant differences observed in the nitrate and nitrite levels that were recorded at one of the farms that was located close to the outlets of a large number of shrimp farms.

3.5 Comparison of nutrient discharge

No significant differences were found in the water quality parameters between the cages which contained fish that were fed either pellet or trash fish diets. In the absence of measurable differences in the water quality parameters, estimations of the theoretical

FIGURE 19
Phosphate levels at different farms in Indonesia



differences in nutrient input and output were made using nutrient flow analysis. In order to undertake the analysis, Kasetsart University, Bangkok provided the analysis for total phosphorous (AOAC, 1980) and nitrogen content (AOAC, 1980) in the pelleted feed. The proximate analysis for the whole fish and the associated percentage moisture content were taken from Boyd *et al*. (2008).

On a wet weight basis, the pellet feed had a higher total phosphorus and nitrogen content than the trash fish (Table 5). However, it should be noted that the pellet feed contains only 10 percent moisture and the trash fish 75 percent.

The proximate composition of the diets is presented in Table 6. On a dry weight basis, the total phosphorus concentration of the two dietary treatments is similar. In contrast, the total nitrogen concentration in the trash fish is higher than that observed in the pellet feed.

TABLE 5
Total phosphorous (P) and total nitrogen (N) levels in trash fish and pellets (wet weight basis)

Total P & N (wet weight)	Pellets	Trash fish
Total P (%)	1.6	0.4
Total P (mg/g)	16.0	4.0
Total N (%)	7.2	3.4
Total N (mg/g)	72	34

TABLE 6
Total phosphorous (P) and total nitrogen (N) levels in trash fish and pelleted feeds (dry weight basis)

Total P & N (dry weight)	Pellet	Trash fish
Total P (%)	1.7	1.6
Total P (mg/g)	17	16
Total N (%)	8	13.6
Total N (mg/g)	80	136

The calculated nutrient intake using pellet and trash feeds is presented in Table 7. The calculations are based on FCRs of 2.5: 1 and 7.5: 1 for feeding pellet feed and trash fish, respectively.

TABLE 7
Calculated total phosphorous and total nitrogen intake levels by fish fed trash fish (wet weight basis) and pellets (dry weight basis)

Total P & N (dry weight)	Pellet (10% moisture)	Trash fish (75% moisture)
Food conversion ratio (FCR)	2.5:1	7.5:1
Total P (mg/g)	17	4
Total P intake (mg/g fish grown)	42.5	30
Total N (mg/g)	80	136
Total N intake (mg/g fish grown)	200	1020

3.6 Sediment quality

As the organic loading of the sediments takes place over time, changes in organic sediment loading can be used as a long-term indicator of environmental change. Benthic sediment samples were collected close to the cages and at a reference site at least 500 metres from the cages. Samples were collected using either a van Veen grab for hard sediments, or a corer for soft sediments.

Sediment samples were characterized according to the following criteria:

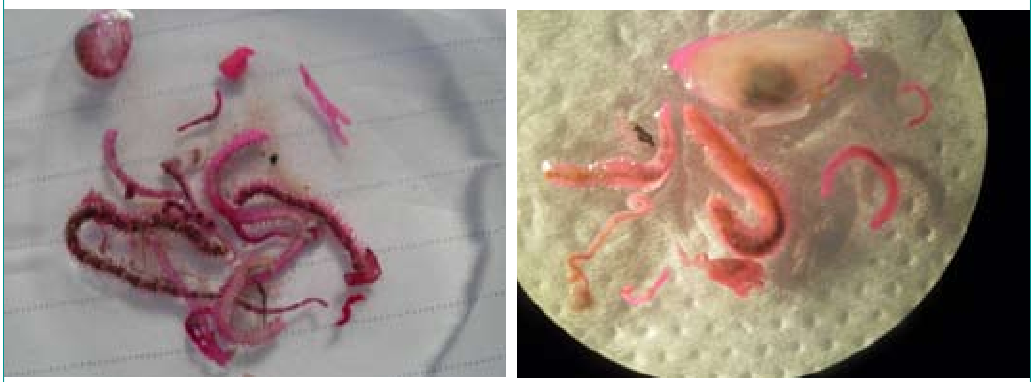
- Sediment type - shell hash, gravel, sand, or mud (silt and/or clay);
- Surface colour and colour change with depth - as a possible indicator of anoxia;
- Smell - sulphide (H_2S or a rotten egg smell), oily (petroleum tar), or humic (a musty, organic odour). Typically, un-impacted sediments have no particular odour;
- General sediment colour - black, green, brown, red, yellow etc.

The sediment samples were sieved in the water until all the fine material had passed through the sieve, and only the particulate matter remained. These particles were then carefully transferred to a plastic sample jar. All the material that was retained on the sieves was transferred to the sample jar, fixed in formalin (4 percent formaldehyde solution), and stained with a Bengal rose stain. The samples were labelled with the date, time, location, and the water depth at which they were taken. During the collection period, the samples were stored on ice, and subsequently refrigerated prior to analysis. Sample sorting was undertaken in a laboratory using a stereo microscope (Figure 20). Samples that were black, 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.

FIGURE 20
Benthic sedimentary faunal analysis

The analysis of the sediment samples showed a wide range of species in the sediments, and that they were not dominated by polychaetes or indicator species (Figure 21). This means there were

FIGURE 21
Sediment fauna found in samples below the test cages



Indonesia *Thailand*

low impacts associated with the sediments below the cages and, furthermore, that there was no measurable differences in the impacts associated with the cages of fish that were fed either the trash fish or pelleted feeds.

Stocking density

The absence of observed differences in the water quality data between fish fed the trash fish and those on pellet feeds, and the concomitant lack of impacts on the sediments under the cages can primarily be attributed the low stocking densities of the cages, and low production biomass on the farms.

Typically the stocking densities in the trial cages were low. Cages of 3m x 3m x 3m with a total volume of 27 m^3 were stocked at a density of 2.6 kg/m^3. This gave a stocking density of 7.7 kg/m^2 (cage surface area). At these densities, 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/m^3. This would give a stocking density of 30 to 45 kg/m^2 (cage surface area). At these densities, the environmental impacts between the farming activities are likely to be high (White *et al*., 2007).

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 undertaken to determine the level of overfeeding by the farmers in Viet Nam and Thailand. Prior to feeding, a feeding tray (50 cm x 50 cm x 10 cm deep) was placed in the centre of the cage and lowered to the bottom. The farmer was asked to weigh the pellets that would typically be used in a feed round, and subsequently feed the ration normally. After the feed round had been completed, the feeding tray was recovered, the number of uneaten pellets counted, and an estimate of the level of overfeeding was made (Figure 22).

FIGURE 22
Feeding tray and waste feed, Viet Nam

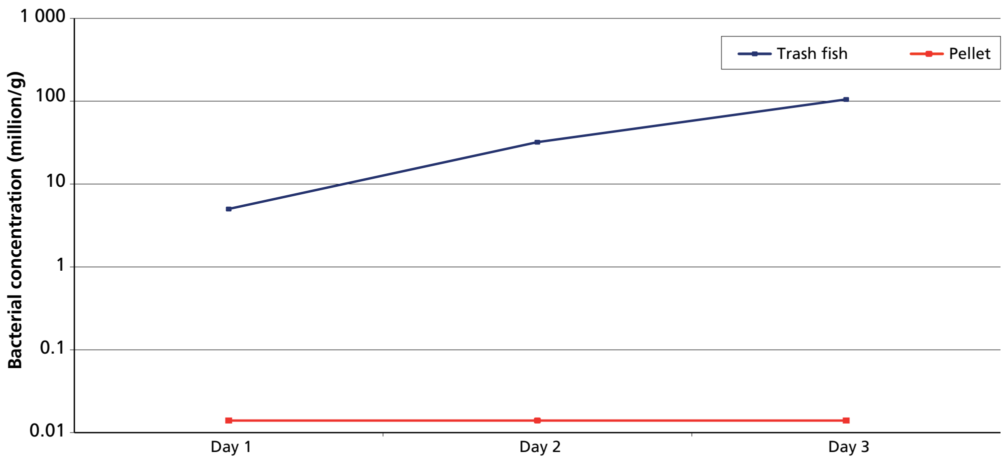
The results of the individual trials indicated an average of 228 uneaten pellets (20.45 g) in the feeding trays (0.25 m^2). Taking into consideration the distribution of uneaten pellets at the bottom of the cages, it was estimated that the farmer had been overfeeding the cages by 11.2 percent. It was assumed that the other farmers were also overfeeding at a similar rate.

3.7 Pathogen transfer

Both cultured and wild fish are susceptible to similar pathogens and parasites. Intensive culture conditions can increase their prevalence in culture populations significantly. As water moves between the farm enclosures and the wider environment, there is a risk of pathogen and parasite transfer between the wild and cultured fish. Disease transmission can also occur when farmed fish escape and mingle with the wild fish, or when whole "infested or infected" fish are used as a feed. In this regard, there is a risk of bacterial pathogen transfer to the cultured fish from feeding infected trash fish, and it is recommended that prior to use, trash fish is sampled and screened for diseases.

To establish the potential for feeds to harbour disease vectors, a test was undertaken at the Main Centre for Mariculture Development (MCMD, Bandar Lampung, Indonesia), to analyse the bacterial loadings of trash fish and pellet feed samples that had been stored on ice for three days. The trash fish and pellets were analysed for total bacterial counts per gram of sample. An ANOVA of Squared Deviations showed significantly ($P<0.05$) higher bacterial loadings in the trash fish than the pellet feeds and that this loading increased over time (Figure 23).

FIGURE 23
Bacterial concentrations in trash fish and pellet feeds stored over time



3.8 Trash fish/low-value fish quality

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

- Low quality trash fish at a price of US$0.24/kg
- Medium quality trash fish at a price of US$0.34/kg
- High quality trash fish at a price of US$0.43/kg

In Indonesia, trash fish is delivered to the farmers every three days. On arrival at the farm, the fish is 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 head or tail)
- Trash fish without the stomach
- A combination of trash fish and fish processing wastes (heads and tails)

3.9 Bacterial levels in water column

The use of trash fish, particularly low quality trash fish or trash fish that has been stored for a number of days can potentially increase the bacterial loading of the water column. In addition, uneaten trash fish may remain at the bottom of the net, further increasing the prevalence of bacteria.

A comparative trial was undertaken by MCMD (Lampung, Indonesia) to measure the bacterial levels in the water column when either trash fish or pellet feeds were fed to the fish. Prior to use, the trash fish was stored on ice. The trial was designed to establish the bacterial loading of the water column when the two types of feed were applied. The trial involved feeding pellet feeds and different qualities of trash fish (1-day old, 2-day old, and 3-day old), and comparing the associated total bacterial counts in the water column.

In order to model the impact of the feeds on the bacterial levels in the water column over time, feed samples were placed in 500ml of sterilized seawater, and the water was subsequently analysed for total bacteria and vibrio (cfu/ml). The following sampling schedule was used:

- before the introduction of the feed
- 20 seconds after the feed had entered the water (simulating the time between feeding and the food being ingested by the fish)
- 1 hour after the feed had entered the water (simulating feed that had not been eaten, but remained at the bottom of the net).

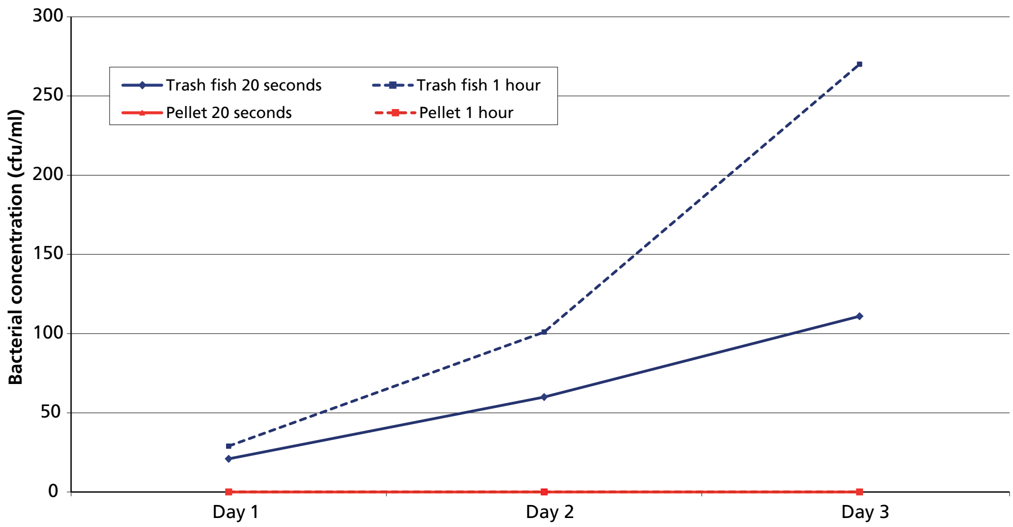
The results were analysed using an F-test to make comparisons of the components of the total deviation. Statistical significance was tested for by comparing the F test statistic where

F = Variance between treatments/variance within treatments

The F-test was used to test the null hypothesis that the sample variances were the same (i.e. H0:*var1=var2*) or reject the null hypothesis to indicate that the sample variances were different. The value(s) returned by F-test were deemed to be statistically significant if the value was 0.05 or less.

The results demonstrated that in comparison with the use of pellet feeds, the use of trash fish significantly ($P<0.05$) increased bacterial levels in the water column, and that bacterial levels increased as a function of the length of time the material was exposed to the water, and the length of time the trash fish had been stored before it was used (Figure 24).

FIGURE 24
Bacterial concentrations in water exposed to trash fish and pellet feeds



3.10 Nutrient leaching to the water column

Potentially, the use of trash fish (particularly low quality trash fish or trash fish that has been stored for a number of days) could increase the nutrient levels in the cages. In this regard, nutrient enrichment could occur during the period between feeding and ingestion. In addition, uneaten trash fish and feed pellets that remain on the bottom of the net will continue to leach nutrients.

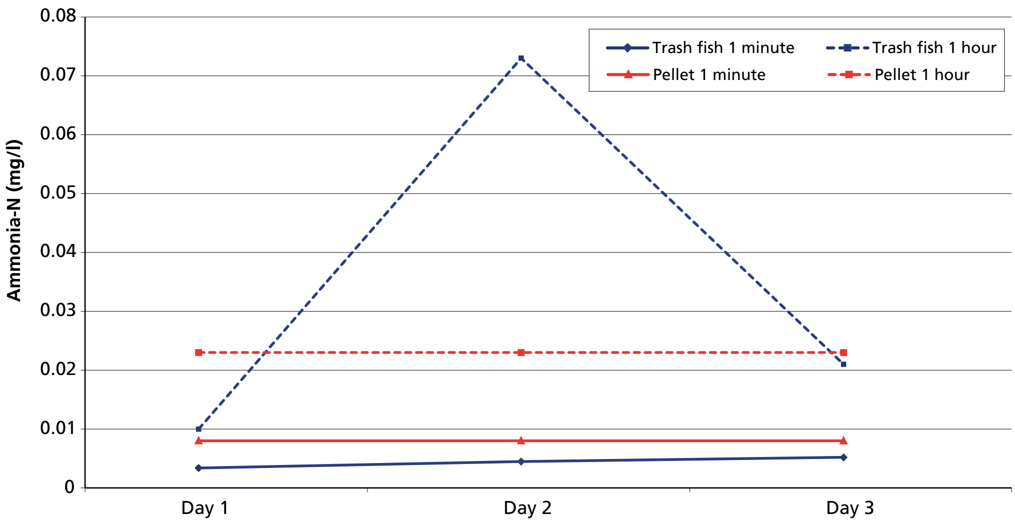
A trial was undertaken by MCMD (Lampung, Indonesia) to measure feed derived nutrient leaching to the water column during feeding. The leaching properties of three different qualities of trash fish (1 day, 2 day, and 3 day old fish) and pelleted feeds were established. The level of leaching was measured as a function of NH_3, NO_2, NO_3 and PO_4 concentrations in the water column.

In order to model the leaching rates, 100 grams of feed was placed into 500 ml of seawater, and analysed for dissolved nutrients over three time periods, *viz*,

- before the feed entered the water (baseline nutrient levels)
- 20 seconds after the feed entered the water (simulating the time between feeding and the food being ingested by the fish)
- 1 hour after entering the water (simulating the feed not being eaten but remaining at the bottom of the cage)

The results describing the levels of ammonia nitrogen (NH_3-N) in the water are presented in Figure 25. In contrast with the pellet feed, the NH_3-N concentrations were significantly higher ($P<0.05$) in the water that was exposed to the trash fish, and that the leaching from this feed source increased after the second day of storage and decreased after the 3rd day of storage.

FIGURE 25
Effect of feed type and storage periods on the NH_3-N concentration in the culture water



The results indicate that when submerged in the water for one hour, the pellet feed leached significant amounts of nitrite (NO_2-N) into 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 (Figure 26).

Nitrate (NO_3-N) leaching was found to be significantly higher ($P<0.05$) when pellets were immersed in water for one hour (Figure 27). In addition, the levels of nitrate observed from the trash fish that had been stored for one day and left in the water for the one hour period were elevated above those samples that has been stored for two or three days.

Phosphate (PO_4-P) leaching was observed to be highest when the pellet feed was immersed in water for one hour (Figure 28). In contrast, the level of phosphate

FIGURE 26

Effect of feed type and storage periods on the NO_2-N concentrations in the culture water

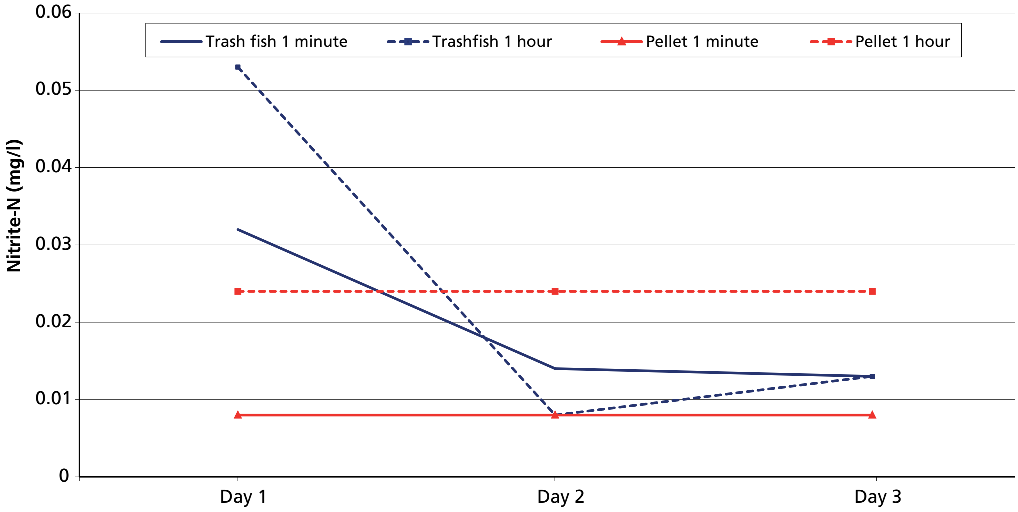


FIGURE 27

Effect of feed type and storage periods on the NO_3-N concentrations in the culture water

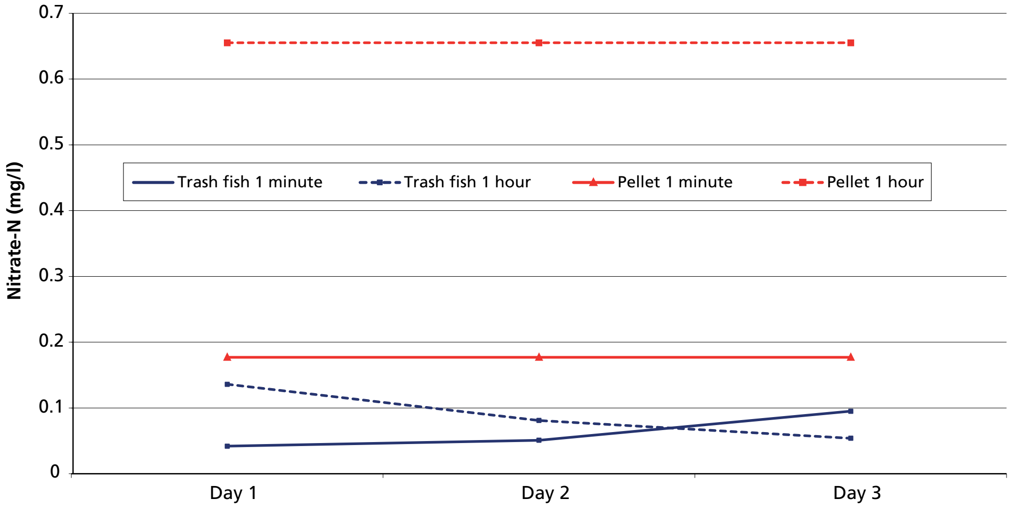
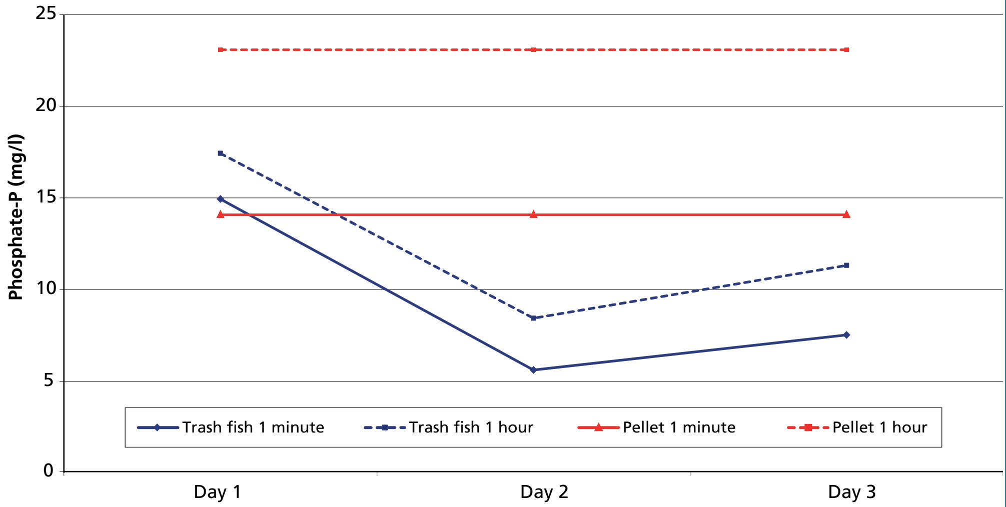


FIGURE 28

Effect of feed type and storage periods on the PO_4-P concentrations in the culture water



leaching was significantly reduced ($P<0.05$) when the pellets were immersed for only one minute. In trash fish, the level of leaching was slightly higher in fish that had been stored for one day. Increasing the storage period to two and three days reduced the level of leaching.

3.11 Comparison of energy use

The energy required to produce aquafeeds varies between feed type (trash fish or pellets) and manufacturing processes. In Norway, EWOS requires 1 040 megajoule (MJ) to produce one tonne of feed (Cermaq, 2009). In contrast, Thai Union uses only 99 kilowatts per tonne of feed produced, which is 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 in the manufacture of the pellet feeds, there are many additional activities and processes that require energy. These energy requirements include the energy expended in:

- fishing for the fishmeal component of the diet;
- production of fishmeal;
- transporting the raw materials to the feed producer; and
- transporting the finished products to the farms.

Pelletier and Tyedmers (2007) estimated that the total energy required to produce 1 tonne of pellet feeds was 18 100 MJ (including transportation costs). Using pellet feeds and assuming an FCR for pellet is 2.45:1, it follows that the energy required to produce the feeds that are required to culture 1 kg of fish is 44.35 MJ.

A similar model can be applied to calculate the energetic costs associated with using trash fish as a feed source. To establish these energetic costs, data was collected from trash fish fishers in Phuket (Thailand), and Bandar Lampung (Indonesia). The manner in which the trash fish are caught, and the energy required for the different processes in the trash fish supply chain can be described as follows:

Phuket, Thailand

Typically, fishing trips that target trash fish are made overnight, and it takes three hours to reach the fishing grounds. Each trip harvests an average of 3 000 kg of fish. The fish is delivered directly to the fish cages and stored for up to three days in insulated boxes containing ice.

- Fifteen litres of fuel is required by the boat to access the fishing grounds (three hours each way). This equates to 548.4 MJ.
- Seven and a half litres of fuel are used for fishing, equating to 274.2 MJ.
- 822.6 MJ (fuel costs) is used to catch 3 000 kg fish equating to 0.27 MJ/kg trash fish
- Between 60 kg and 150 kg of ice is required to keep the fish fresh over a three-day period, equating to 0.09 MJ/kg of trash fish.

Taking the energy supply costs into consideration, the total energy required to produce one kg of trash fish is 0.36 MJ. Based on a mean FCR of 11:1, the amount of energy required to grow 1 kg of fish using trash fish equates to 3.96 MJ.

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

Bandar Lampung, Indonesia

On average, commercial fishing trips last for seven days and use 2 600 litres of fuel to catch seven tonnes of fish. Typically, the catch comprises 2 800 kg of trash fish and 4 200 kg of squid and fish for human consumption. The proportion of the fuel that is used to catch the trash fish equates to 1 040 litres with an energy equivalent of 38 022 MJ, which, based on an average catch of 2 800 kg of trash fish, equates to 13.58 MJ/kg trash fish caught. At an FCR of 6 (grouper culture in Indonesia, Table 9) the amount of energy required to grow 1 kg of fish equates to 81.48 MJ.

FCR of 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 kg of fish. In Thailand, using a small dedicated boat for catching trash fish, 3.96 MJ was required to produce one kg 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 kg of fish.

3.12 Fish-in Fish-out Ratio (FIFO)

One of the current debates 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 it takes to produce one tonne of farmed salmon. One such methodology is based on the fish-in fish-out (FIFO) ratio. Using dry pellets, FIFO ratios for salmon range between 3:1 to 10:1. In this regard, Tacon and Metian (2009) calculated a FIFO ratio of 4.9:1 for salmon production, which means 4.9 tonnes of wild fish are required to produce 1 tonne of farmed salmon.

A number of authors have developed methodologies for calculating FIFO ratios. These include:

- Tilapia Aquaculture Dialogue draft v2.0 (WWF, 2009),
- Tacon and Metian (2009),
- International Fishmeal and Fish Oil Organisation (IFFO) methodology (Jackson, 2009),
- EWOS methodology for fatty fish such as salmon (EWOS, 2009)

The following provides a brief review of the assumptions that are used in the various models.

1. Tilapia Aquaculture Dialogue draft v2.0 Methodology

These models are based on the weight of fish caught and produced, and provide Fish Feed Efficiency Ratios for fishmeal and fish oil.

$$\text{FFERmeal} = \frac{(\%\ \text{fishmeal in feed}) \times (\text{eFCR})}{22.2}$$

$$\text{FFERoil} = \frac{(\%\ \text{fish oil in feed}) \times (\text{eFCR})}{5.0}$$

The model assumes that the fishmeal produced from the fish caught for fish oil is wasted.

2. Tacon and Metian (2009)

The method used by Tacon and Metian (2009) effectively assumes that the excess fishmeal produced from the fish caught for fish oil is wasted. In fact it is used as ingredients and materials in other feed production systems. The IFFO (2009) method addresses this issue but fails to recognise that cultured salmon have a higher lipid level than the average wild fish. The models assume a yield of fishmeal and fish oil of 22.5 and 5 percent on a wet weight to dry weight basis, respectively.

3. IFFO methodology (Jackson, 2009)

The IFFO method applies the following equation:

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

This model takes into account both the fishmeal and fish oil use, which corrects the Tacon and Metian (2009) model that implies that the extra fishmeal is wasted. However, the model is biased against fish with high lipid levels such as salmon, trout and eels. The bias is a result of the differential between some species of cultured fish that have higher lipid levels than the wild fish used for the production of the fishmeal and fish oil.

4. EWOS methodology

The EWOS model compensates for fish that have relatively high fish oil concentrations (e.g. salmon) on the basis of nutrients used and produced, and compares the ratios using the same assumptions (fishmeal and fish oil yields). The nutrient based ratio corrects for the differential oil concentrations, and is the preferred ratios to use for fatty fish such as salmon, trout and eels. The calculations are as follows:

For marine protein

$$\text{Marine protein dependency ratio} = \frac{\text{kg marine protein used}}{\text{kg marine protein produced}}$$

$$\text{MPDR} = \frac{\text{FMfeed} \times \text{PrFM} \times \text{eFCR}}{\text{PrtSalm}}$$

where

MPDR	Marine protein dependency ratio
FMfeed	Concentration of fishmeal in the feed (%)
PrFM	Concentration of protein in fishmeal (as a proportion)
eFCR	economic feed conversion ratio
PrtSalm	Concentration of protein in the salmon on whole fish basis (%)

For marine oil

$$\text{Marine oil dependency ratio} = \frac{\text{kg marine oil used}}{\text{kg marine oil produced}}$$

$$\text{MPDR} = \frac{(\text{Fofeed} \times \text{FMfeed} \times \text{FoFM})) \times \text{eFCR}}{\text{OilSalm}}$$

where

MODR	Marine oil dependency ratio
FoFeed	Concentration of fish oil in the feed (%)
FMfeed	Concentration of fishmeal in the feed (%)
FoFM	Concentration of fish oil in fishmeal (as a proportion)
eFCR	economic feed conversion ratio
OilSalm	Concentration of oil in the salmon on whole fish basis (%)

For the purpose of this report, the IFFO formula was adopted and used to analyse the results of this study for two reasons: the trial species do not have high lipid levels when compared to salmon and the model accounts for the other uses of the unused fishmeal and fish oil.

The reported use of fishmeal and fish oil in the EWOS and Thai Union formulated diets were remarkably similar. The reported fishmeal and fish oil used in the EWOS test formulation (Dave F.H. Robbs, EWOS Viet Nam, Ho Chi Minh City, Viet Nam, personal communication, 2010) comprised:

- Fishmeal: 30 percent - Group 1 Scandinavian fishmeal (Norway)
- Fish oil: 8 percent (Denmark)

The reported use of fishmeal and fish oil used in the Thai Union formulation (Supis Throngrod, Thai Union Feed Mill Co., Ltd., personal communication, 2010) comprised:

- Fishmeal: 30 percent of the barramundi feed (fishmeal was locally sourced).
- Fish oil: approximately 7.5 percent of the feed (source of fish oil was locally produced tuna oil).

The average food conversion ratios recorded for the different fish species in the different case study countries using pellet feeds and trash fish are presented in Tables 8 and 9.

The average FCRs attained using pellets and trash fish across all the trial in four countries was 2.45:1 and 9.02:1 respectively. These ratios were used to estimate FIFO ratios for tropical marine fish as follows:

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

$$\frac{30 + 7.7}{22.5 + 5} \times 2.45 = 3.34$$

The results indicate that the FIFO ratio from pellet feeds was 3.34:1, which is much lower than the 9.02:1 FIFO ratio from trash fish.

TABLE 8
Mean feed conversion ratios for fish fed pellets in the study trials

Pellets	China	Indonesia	Thailand	Viet Nam	Average
Orange-spotted/brown-marbled grouper	2.57	2.41	3.09		2.69
Red snapper	1.31			2.20	1.75
Barramundi			2.55		2.55
Snubnose pompano				2.84	2.84
Average					2.45

TABLE 9
Mean feed conversion ratios for fish fed trash fish in the study trials

Trash fish	China	Indonesia	Thailand	Viet Nam	Average
Orange-spotted/brown-marbled grouper	12.33	6.00	13.17		10.50
Red snapper	5.15			9.00	7.08
Barramundi			5.51		5.51
Snubnose pompano				13.00	13.00
Average					9.02

4. CONCLUSIONS

The results from the environmental assessment demonstrate that there were no significant differences in the impacts between the use of aquafeeds (either pellet or trash feeds) on the water quality and the sediment characteristics beneath and around the fish cages. These results may be attributable to the low stocking densities of the trial farms, and in this regard, higher stocking densities and associated input levels may have yielded different results.

The main findings of the study are as follows:

- There were no significant differences in the environmental impacts associated with the use of trash fish/low-value fish and pellet feeds;
- The choice of culture species did not significantly affect the environmental impacts associated with the use of aquafeeds;
- 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;
- 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;
- The estimated energy cost of producing one kilogramme of farmed fish using trash fish/low-value fish as a feed source was significantly lower than that required when using pelleted feeds based on the use of small boats in artisanal fishing, but higher when the trash fish/low-value fish was harvested by big commercial fishing boats; and
- 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).

The implications of the findings on policy, management, and for the development of future research programmes include:

- A policy is required to encourage the development of suitable pelleted diets for high value fish in cages. This will reduce fishing pressure on feed fish/ trash fish stocks, promote the growth of high value cage farming, and negate the seasonal constraints associated with feed fish supply.
- Further research is required to establish why there was such a wide variation in the FCRs reported from the different study countries using pellet feeds. For example, in Indonesia, farmers culturing grouper reported FCRs of 2.41:1, while farmers in Thailand obtained FCRs of 3.09:1. Likewise in China, farmers culturing snapper reported FCRs of 1.31:1, while in Viet Nam, farmers culturing the same species reported FCRs of 2.2:1.
- Further research is required to determine why there are differences between the FCRs achieved when using feed fish (trash fish) diets, and to determine the influence that feedfish source has on nutritional indices. For example, the use of fish processing waste, low-value fish, and prepared feedfish (head off, and filleted trash fish).
- There is a need to develop better feed management guidelines for using pelleted feeds.

The apparent lack of significant differences in the environmental impacts that accrue to the use of different feed types was attributed to the low stocking densities used at the trial sites. This finding confirms the importance of farming within the carrying capacity of the culture site. In particular, it underlines (i) the need for regulation, preferably supported by a carrying capacity assessment, that limits the number of cage farms in a site to an optimal density, (ii) the need for technical guidelines and extension advice to encourage better farm management, and improved feeding and feed management practices, and (iii) the need for quality, low polluting feeds.

Saving energy and reducing the fish component in feed formulations are global as well as wider industry concerns. However, better site management and introducing better management practices would also address issues of improving energy and feed efficiencies.

While it was not within the scope of the study, it was evident that the disease and abiotic factors that resulted in mortalities were exacerbated by impacts from sources other than the cage farms. This further highlights the importance of a policy and plans that consider the competing objectives on the uses of coastal waters and designating mariculture zones. Farms in these zones would be easier to service, monitor and regulate. Furthermore, if the farmers in the zone were organized into an association, they would also benefit from economy of scale.

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Trading of low-value fish in a cage farm, Bandar Lampung, Indonesia. In Indonesia, fishers are mostly small-scale and artisanal and over 75 percent of the fishers are reported selling the low-value fish directly to the cage farmers.

Courtesy of FAO/Mohammad Hasan

Trading of trash fish/low-value fish in Zhanjiang, Guangdong, China. In China, fishers are mostly large-scale and use industrial trawler for fishing. These fishers generally bring the fish to the selected landing centres and trash fish/low-value fish suppliers/traders buy the fish to supply to the cage farms.

Courtesy of FAO/M.C. Nandeesha

ANNEX 3

Impacts of pellet feed use in marine cage culture on the sector and livelihoods[1]

EXECUTIVE SUMMARY

This report synthesizes the results of three project activities that were aimed at understanding the technical implications and the potential social and economic impacts of a shift from trash fish/low-value fish (TF/LVF) to pellet feeds in marine cage culture. The study focused on the livelihoods of fishers and traders of trash fish/low-value fish, and on farmers and farm workers. The three activities comprised (i) the survey, before the farm trials were established, of the livelihood assets, strategies and options available to fishers and traders, and their perceptions of the livelihood impacts of a switch to pellet feeds; (ii) the assessments of the perceptions of the trial farmers and non-trial farmers on the use of pellet feeds before and after the farm trials. This second activity included follow-up interviews with some of the fishers and traders who had been respondents of the first survey; and (iii) a follow-up mission to the project sites in Indonesia, Viet Nam and Thailand. The mission was undertaken 16 months after the completion of the farm trials, and was designed to confirm and refine the issues and recommendations that were made at the final regional stakeholders' workshop. This process was undertaken through individual or group discussions with government fishery officers, participants, and observers of the farm trials.

Fishers' perceptions and their outlook on their livelihoods. The baseline survey of the fishers and suppliers of trash fish/low-value fish showed that in general, a wholesale switch to pellet feeds would not have a disastrous impact on their livelihoods; there were alternative markets that they could access. Their first option would be to sell the trash fish/low-value fish to fishmeal producers. Fishmeal production currently accounts for a significant proportion of the catch of the Chinese fishers, and represents a market for the bycatch of the Indonesian, Thai and Vietnamese fishers who fish for food grade fish. A second option would be to improve on-board handling and preservation, and selling the low-value fish for processing in the salted fish sector, or as other product forms. With the exception of Thailand, daily sales of food fish are higher than those of trash fish. This suggests that the fishers target food fish, and sell the low-value fish which is a bycatch or is food fish that has become degraded on board. In contrast, Thai farmers reported low sales of food fish as they generally fish for home consumption and, as most of them have cage farms, use the bycatch or low-value species to feed their stock. In China, the average daily sales of low-value fish and food fish were valued at US$50 and US$84 respectively. In Indonesia, these figures were US$24 and US$53, in Thailand US$24 and US$15, and in Viet Nam US$7 and US$42. An interview with a long time fisher in China revealed that he would lose money if most of the catch were sold for fishmeal processing.

[1] This annex has been prepared based on the consultancy reports of Dr Nguyen TT Thuy and Dr Mudnakudu C. Nandeesha, FAO Consultants to the project and on pertinent findings of the follow-up mission undertaken during 7 to 23 July 2011.

One point of difference between the countries was that the Chinese fishers, who use trawlers and employ a good number of crewmen, have almost no alternative livelihoods to fishing. In contrast, the fishers in the other countries have other livelihood activities including crop production, livestock and fish farming. Primarily these fishers target food fish, and sell the low-value fish or use them in their own fish farms. Should fish farmers switch to pellet feeds, they can still sell their low-value fish to the fishmeal producers. Chinese fishers would seem to be the most vulnerable to a complete switch over from trash fish to pellet feeds. On the other hand the presence of a ready market in the fishmeal processing sector would cushion this impact; their fear is that without any other buyer, the fishmeal processors might reduce the buying price for their trash fish. At present, the price offered by the fishmeal processors is lower than that of the cage farmers. A more serious threat to their livelihoods is the overexploitation of the low-value demersal fish stocks that they are targeting. In this regard, it appears they are being kept solvent by a fuel subsidy. The fuel subsidy helps to maintain the already intense fishing pressure in their traditional fishing grounds (estimated at around 10 000 trawlers that use 450– 600 hp engines). This threat is highlighted by the survey results which show that on average, their fishing activities earns them an income of US$3 744 per annum.

The degree of the fishers' dependence on and the contribution of fishing to, household incomes were found to vary. The major rationale to become involved in fishing was the ease of access to fisheries resources. The contribution of fishing to household income was to some extent influenced by the diversity of livelihood options, and the assets that the fishers possessed. A fairly large majority of the fishers were found to earn more from fishing than from other activities.

Assets are indicative of an household's resilience to a disruption in their livelihoods. Chinese fisher households had no livestock; Indonesian households had few livestock; more than 40 percent of the Vietnamese households reported rearing poultry, and nine percent raised cattle. Many Thai fishers reported having arable land, fish farms or both, and nearly 90 percent of the fishers owned their houses. All the fishers reported having access to credit from informal and formal sources, although common complaints were the high interest rates on loans, and that the loans they are eligible to apply for were insufficient for their needs. Savings was a common household strategy, however common savings funds were rarely reported. Social capital in the form of institutional support was fairly strong, and their outlook for a secure future was viewed in terms of having enough savings, and ensuring that their children were well educated. In contrast to the other countries, the Chinese fishers had options to take part in government managed pension plans.

The fishers' belief that their major livelihood was not seriously threatened was reflected by the qualitative assessments carried out before and after the production trials. The concerns expressed were not about losing a market for their fish, but rather earning less income from having to sell it to the fishmeal processors. The exception was the Indonesian fishers who obtain a higher price from fishmeal producers, but were unhappy with the delayed payment by the factories. In contrast, the fish farmers pay cash on, or at most two days after delivery. Traders of trash fish were not so concerned about the potential changes in markets as they already have a market for their fish in terms of the fishmeal processors as well as other sources of income.

Perceptions of the fish farmers towards the use of pellet feeds. The rapid rural appraisal that was conducted at the start of the project revealed that many of the problems that the farmers experienced related to their use of trash fish/low-value fish. These included its availability, fluctuating prices, uncertainties in trash fish/low-value fish supply, transport and storage. Trash fish/low-value fish is not readily available, and during closed seasons or inclement weather, it has to be bought in from other regions.

The follow-up mission established a number of additional issues with the use of trash fish/low-value fish. These included their contamination with chemical preservatives, the added labour and transport costs required to bring the fish to the farm, and the cost of preserving fish quality while on storage at the farm site. Most of these add to production costs and subsequently affect the farm performance. These issues seem to have weighed sufficiently on farmers' concerns for their welfare, and thus the promise of less drudgery and improved yields would have stimulated their interest in the use of pellet feeds. The combination of convenience, improved performance in terms of FCR, cost of production, and flesh quality were the basis of their positive perception of pellet feeds. The trials afforded them the opportunity to experience feeding fish with pellets, and see the results.

Changes in perceptions assessed immediately after the trials varied according to the results of the trials. They also reflected previous experiences with using pellet feeds (some farmers had been using them as complete feeds or in combination with trash fish), and their access to trash fish/low-value fish. While some farmers reported that trash fish/low-value fish was easily sourced from suppliers, others reported fishing for their feed fish or using bycatch as feed. The trials made some impact on some well-entrenched attitudes, including those that the flesh of fish raised on pellets is inferior to that of fish raised or finished on trash fish/low-value fish and, importantly, removed the doubt as to whether grouper could be weaned and grown successfully on pellet feeds.

The follow-up mission confirmed these qualitative changes in perceptions. It also revealed specific issues that influence farmers' choice of trash fish/low-value fish, their preferences for either trash fish/low-value fish or pellet feeds, and clarified their motivations for switching to pellet feeds. Farmers were aware and understood clearly that pellet feeds produced better or slightly better FCRs than feeding trash fish/low-value fish. Most farmers, and especially their wives, like the convenience afforded by the use of pellet feeds. However, reservations were expressed on the non-specificity of the available feeds to the species and life stage levels. It was also noted that pellet feeds were difficult to access as feed dealers were scarce, or there are none, and that there was often insufficient capital for the significant cash outlay required to buy the feed. The farmers that continued to use trash fish/low-value fish did so because the supply and lower price was compatible with their cash flows.

Two non-feed issues – seed and disease - are relevant to farmers' understanding and appreciation of the feed, feeding practice, profitability, and the adoption of pellet feeds. The lack of a reliable supply of quality seed for their culture species, or of the higher value species that they would like to culture, can be of more concern and presents a greater production constraint than having access to pellet feeds. In terms of feed supply, they have existing sources of trash fish/low-value fish that they can use, but if the seed is not available, they simply cannot farm. The mission found that the farmers would be prepared to invest more on nutrition, disease prevention, and other technical inputs including pellet feeds if, (i) they had a reliable supply of quality seed enabling them to fulfil market demands, and (ii) they were rearing a higher value species.

In the current farming operations, disease accounts for significant financial losses. Mortality is typically in the region of 40 percent and, with severe infections, can be as high as 100 percent. In response to the high prevalence of disease, Indonesian and Vietnamese farmers pay more attention to health management than feed management. As a result, the relationship between profitability and good feed/feed management practice tends to be less of an issue to the farmers than profitability and disease control. In contrast, the Thai farmers use lower cage densities and stocking rates and are therefore less susceptible to disease. However, their farms tend to be located in estuaries, and are vulnerable to sudden influxes of freshwater that can kill their stock. Such events have occurred in the recent past.

Finally, the general indication from the project, particularly from the follow-up mission, is that the more progressive farmers - those who practice better management, specifically better feed management practices - tend to be more aware, and have a better understanding of, the technical and economic advantages associated with using pellet feeds. This predisposes them to the adoption of these feeds. Nevertheless, there are many constraints to the adoption of the pellet feeds. These constraints can be seen as areas for key technical assistance and innovation. The following key generic areas that require assistance include:

1. Promoting supplies of quality seed that are designed for the culture species of choice;
2. Assisting farmers to acquire the capital to purchase pellet feeds through the provision of credit, savings, or other financial means;
3. Enabling the farmers to purchase feed in bulk, and at a discount;
4. Making it convenient and cheaper to access pellet feeds;
5. Producing feed formulations that are both species-specific and growth-stage specific;
6. Providing farmers with the technical and management advice and problem-solving assistance that they require to optimize their use of the pellet feeds. This advice could be sought from feed agents, government extension workers and technical specialists.

These interventions could be facilitated by the farmers being organized into farmer groups or associations. These would increase the economy of scale of their operations, strengthen their buying and marketing leverages, and reduce service costs.

1. INTRODUCTION

Three activities were undertaken to determine how a shift from trash fish/low-value fish to pellet feeds would impact the livelihoods of fishers, fish traders, farmers and farm workers. The first activity was a baseline survey that was undertaken prior to the farm trials. The survey was designed to determine the livelihood assets, strategies and options available to fishers and traders of trash fish/low-value fish, and their perceptions of the impact that a switch to pellet feeds would have on their livelihoods. The second activity was an assessment of the perceptions of trial and non-trial farmers on the use of pellet feeds – this was undertaken prior to, and after, the production trials. This second activity included follow-up interviews of some fishers and traders in trash fish/low-value fish who had been respondents of the baseline survey. The third activity was a follow-up mission several months after the completion of the farm trials. This mission was designed to confirm those issues that have been identified during the trials, and assess the recommendations that had been made during the final stakeholders' workshop.

1.1 Objectives

(i) The overall objective of the baseline survey of fishers' livelihoods was to assess the potential impacts that the switch to pellet feeds by the marine cage culture sector would have on fisher livelihoods and the associated individuals involved in the supply of trash fish/low-value fish, their ability to cope with these impacts, and the opportunities that were open to them to address these impacts.

(ii) The objective of the pre- and post-trial qualitative assessments was to assess the changes in farmers' perceptions about the use of pellet feeds. The post-trial assessment included discussions with fishers and traders. These discussions were designed to establish their views on the livelihood impacts associated with the adoption of the pellet feeds.

(iii) The objectives of the follow-up mission was to confirm the earlier qualitative assessments of the changes, or lack thereof, in the farmers' perceptions towards using pellet feeds, and establish the specific influences that lead to these perceptions.

1.2 Methodologies

(i) The baseline survey of the fishers' livelihoods was carried out in the four countries. A structured questionnaire based on personal interviews was undertaken. The total number of fisher households surveyed was 91. Of these, 20 were in China. These surveys included three traders of low-value fish. In Indonesia, eight fishers were interviewed, and in Thailand, 20 surveys including nine fish traders were undertaken. In Viet Nam, 43 surveys were carried out. These surveys included four fish traders. Between January and December 2009, the baseline surveys were conducted by the project coordinators of the participating countries. The survey questionnaire included 20 major questions each seeking more than one response. The survey focused on developing an understanding of the income generated from supplying trash fish/low-value fish, the market for trash fish/low-value fish, including prices, household assets, alternative sources of household income, and livelihood assets. The survey sought to obtain a ranking for a given set of factors that would explain why fisher households were engaged in supplying trash fish/low-value fish, how they would respond to unforeseen financial difficulties, and to provide insight into the fishers' aspirations for their families. The small sample size combined with the variations in sample numbers undertaken across the four countries, as well as the dearth of quantitative information, limited the extent to which the data could be subjected to a robust statistical analysis.

(ii) The subsequent qualitative assessment was based on the results of the baseline survey. This was undertaken in conjunction with the project component "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 to the farmers changing from trash fish/low-value fish to pellet feeds. The methodology that was applied was primarily based on meetings with some of the fishers who had been respondents to the initial baseline survey, and farmer groups that included participating and non- participating farmers, individual farmers, or farmers and their spouses.

(iii) The follow-up mission was carried out in Indonesia, Viet Nam and Thailand (in that order, and between 7 June and 23 July 2011). The mission employed unstructured interviews with trial and non-trial farmers on their farms, followed by a group discussion at the end of each country visit. Project personnel, project coordinators from each country, some invited management, and information and economics experts joined the mission. The discussions included government technical personnel and representatives from feed manufacturers. A stakeholders' workshop was conducted in Thailand with men and women farmers from three provinces (Krabi, Phuket and Phang Nga). Researchers, technicians and extension workers from two government coastal aquaculture centres, fish traders, and technical staff from a feed manufacturing company joined this workshop.

2. FINDINGS

2.1 The outlook for fishers and suppliers of trash fish/low-value fish

Overview. There was a range of trash fish/low-value fish suppliers in each country. In China, the majority of the fish suppliers that were surveyed were large scale industrial trawlers. In contrast, the majority of the small scale fishers that were surveyed were located in Viet Nam. The differential in supplier types between the countries suggests that while China is almost solely dependent on commercial scale sources of trash fish/low-value fish, in other countries, other role players predominate. In a way it also reflects the scale of mariculture of the country.

TABLE 1
Characterization and number of the trash fish/low-value fish suppliers surveyed in the four countries

Supplier type	Country				
	China	Indonesia	Thailand	Viet Nam	Total
Fish farmer/fisher	-	-	9	2	11
Large/industrial trawler	15	-	2	-	17
Middle man and aquaculturist	-	-	1	-	1
Middle man	3	-	8	4	15
Small fisher	2	8		37	47
Total	**20**	**8**	**20**	**43**	**91**

(i) Household activities

a. Fishing

Fishing was found to be the main occupation in 63 of the 91 households surveyed (Table 2). In China, trawling provided the main income to the households, while in Indonesia and Viet Nam, small scale fishing was a major source of income. In Thailand, about half of the fish farmers / fishers and two fish traders indicated that fishing was their main source of family income (Figure 1).

FIGURE 1
Contribution of different income generating activities to household incomes

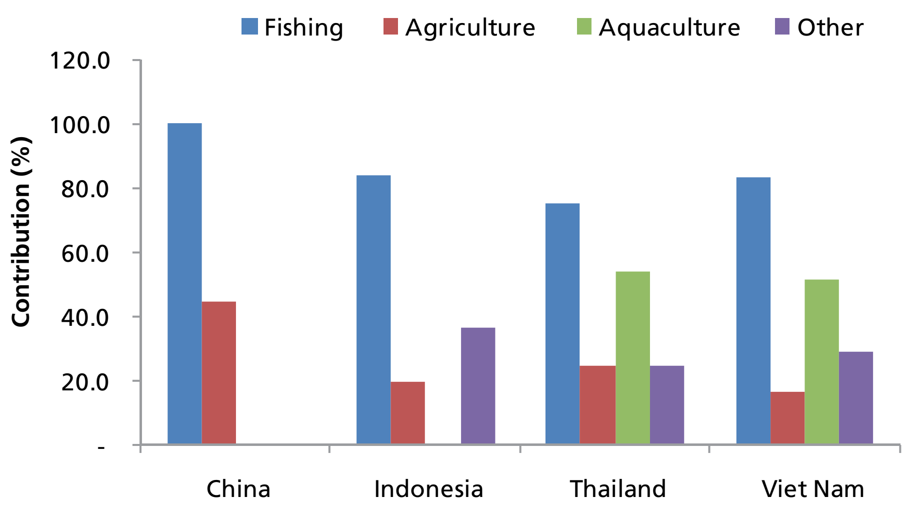


TABLE 2
Fishing as the primary income generating activity for the households surveyed

Country	Number of households per country		
	No	Yes	Total
China	4	16	20
Indonesia	2	6	8
Thailand	11	9	20
Viet Nam	11	32	43
Total	**28**	**63**	**91**

Out of 62 households surveyed, 34 households (three fish farmer/fishers, 15 trawlers, one trader and 15 small-scale fishers) reported that fishery activities provided up to 100 percent of household incomes. In China nearly all of the household income of all the respondents was derived from fishing, while in Viet Nam, the contribution from fishing could be as low as 50 percent of household incomes (Table 3).

TABLE 3
Contribution of fishing to total household income

Country	Minimum (%)	Maximum (%)	Average (%)
China	99	100	99.9
Indonesia	70	100	95.0
Thailand	60	100	85.0
Viet Nam	50	100	83.1
Total	**50**	**100**	**88.9**

Most fishers indicated that they did not specifically target low-value fish. At 40 percent of fishers, China reported the largest number of fishers targeting low-value fish. These figures were 15 and 21 percent in Thailand and Viet Nam respectively. In Indonesia all the fishers reported that they primarily fished for food fish (Table 4).

In all the countries, a component of the catch was used as food fish (Table 5). In Viet Nam, 71.5 percent of the catch was used as food fish. This contrasts to Indonesia where it was only 32.5 percent, despite Indonesian fishers declaring that their primary target is food fish.

The daily and the average annual incomes from fishing were highly variable (Tables 6 and 7). In Indonesia, the lowest daily incomes were recorded at US$2.2/day. In contrast in China, the lowest daily incomes were recorded at US$25.3/day. Between the countries, the lowest maximum income was recorded in Thailand (US$33.33/day), and the highest in China (US$151.52/day). As anticipated, the highest average daily earning was recorded in China (US$83.85/day), and lowest in Thailand (US$15.24/day).

A similar trend was observed in the minimum, maximum and average annual incomes derived from fishing: China recorded the highest average income at US$16 667/annum, and Thailand, the lowest at US$4 693/annum. Fishers in Indonesia and Viet Nam also earned high incomes. The Indonesian finding is somewhat surprising in that all the fishers were small scale and possibly artisanal.

The fishers' earnings from selling their catch directly to farmers are presented in Tables 8 and 9. The number of fishers who sold their catch directly to cage farms varied between the countries. In Indonesia, 75.6 percent of the fishers reported selling their fish directly to the farmers. In contrast, in Viet Nam only 27.5 percent

TABLE 4
Number of fishers catching only low-value fish to supply aquaculture farms

Country	Number of fishers		
	No	Yes	Total
China	12	8	20
Indonesia	8	-	8
Thailand	17	3	20
Viet Nam	34	9	43
Total	**71**	**20**	**91**

TABLE 5
Percentage of the daily catch used as household food

Country	Minimum (%)	Maximum (%)	Average (%)
China (11)	10	100	41.8
Indonesia (6)	10	80	32.5
Thailand (8)	20	80	38.8
Viet Nam (31)	5	100	71.5
Total (56)	**5**	**100**	**56.8**

Values in the parenthesis indicate the number of respondents for each country.

TABLE 6
Daily income derived from sale of food fish

Country	Daily income (US$)		
	Minimum	Maximum	Average
China (5)	25.3	151.5	83.9
Indonesia (6)	2.2	219.3	53.4
Thailand (7)	6.7	33.3	15.2
Viet Nam (27)	5.6	194.4	41.7

Values in the parenthesis indicate the number of respondents for each country.

TABLE 7
Annual income derived from the sale of food fish

Country	Annual income (US$)		
	Min	Max	Average
China (5)	7 576	36 364	16 667
Indonesia (6)	800	68 418	15 336
Thailand (5)	3 600	6 667	4 693
Viet Nam (31)	250	166 667	11 164

Values in the parenthesis indicate the number of respondents for each country.

TABLE 8
Daily income derived from sale of fish to aquaculture farms

Country	Daily income (US$)		
	Minimum	Maximum	Average
China (3)	25.3	80.8	49.6
Indonesia (8)	2.8	54.8	24.7
Thailand (7)	3.3	66.7	24.3
Viet Nam (24)	0.8	55.6	6.9

Values in the parenthesis indicate the number of respondents for each country.

TABLE 9
Annual income derived from sale of fish to aquaculture farms

Country	Daily income (US$)		
	Minimum	Maximum	Average
China (3)	2 466	50 000	23 744
Indonesia (8)	1210	17 105	6 976
Thailand (7)	3 333	17 600	7 787
Viet Nam (24)	111	27 778	1 706

Values in the parenthesis indicate the number of respondents for each country.

TABLE 10
Number of households reporting seasonal variability in fish catches

Country	Number of households
China (12)	12
Indonesia (8)	8
Thailand (17)	17
Viet Nam (34)	34
Total (71)	**71**

Values in the parenthesis indicate the number of respondents for each country.

TABLE 11
Fishers' involvement in the fishing of trash fish/low-value fish

Country	Involvement in the fishing (years)		
	Minimum	Maximum	Average
China (9)	10	30	19
Thailand (1)	20	20	20
Viet Nam (3)	8	20	13
Total (13)	**8**	**30**	**17**

Values in the parenthesis indicate the number of respondents for each country.

reported doing so. This may reflect the fact that many fishers in Viet Nam also owned cage farms or that they consumed much of their catch (Table 5). This inference is supported by Tables 8 and 9 which show the daily and annual average incomes obtained from fish sales to cage farms. In Viet Nam, these figures were US$6.91 and US$1 706 respectively. In China they were US$49.55 and US$23 744 respectively. In Thailand and Indonesia these figures were similar at around US$24 and US$7 000 respectively.

Of the 91 respondents, 71 indicated that there was seasonal variability in their fish catches. In China, August–October was seen as the best fishing period. In Indonesia, the full-moon period and bad weather were identified as factors that resulted in poor fishing. Fishers in Thailand were aware of seasonal variations in their catches, and fishing is banned during the spawning season (May–June). A fisher in Viet Nam believed that the good fishing season was between August–October, while another indicated that this period was between February–June. In contrast, a third respondent suggested January–May was the good fishing season. In Viet Nam, the survey included fishers from the North and North Central coastal regions. These two regions have very different coastal weather patterns, which probably accounted for the variations in the reported fishing seasons.

The number of respondents that reported how long they had been involved in the fishing industry and the size of the craft that they used was low, totalling only 13 and 12 respondents respectively. There were no respondents from Indonesia (Tables 11 and 12). In the three countries, the fishers reported an average experience of over 10 years, with those in Thailand having been involved in the industry for the longest period. The average boat size used in China far exceeded that used in Thailand and Viet Nam.

Tables 13 to 15 and Figure 2 show the relationships between the number of days spent on fishing, the daily catch, the size of the craft, and the daily revenue derived from fishing. As might be expected , the daily revenue from fishing was significantly correlated ($P<0.05$) to boat size (Figure 2); a boat of more than 20 m in length had higher daily catch, and therefore sales. Fishers in China, who use bigger boats than in the other countries, reported fishing for fewer days a month than their counterparts in Thailand and Viet Nam.

The marketing of low-value fish is characterized in Tables 16 to 19. Notwithstanding the small number of responses, the commercial nature of fishing and the sale of trash fish/low-value fish is evident. In China where commercial boats predominate, the sale of fish is not handled by the fishers. This is unlikely to be the case in Thailand and Indonesia, where the majority of the fishers are also direct suppliers to cage farms. Majority of fishers sell their products to

FIGURE 2
Relationship between boat size and daily revenues from fishing

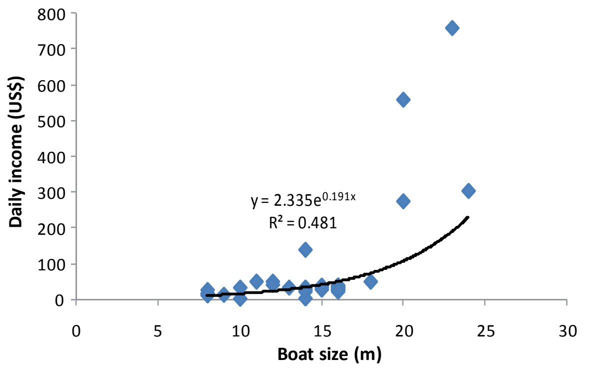


TABLE 12
Size of boat commonly used in fishing

Country	Boat size (m)		
	Minimum	Maximum	Average
China (7)	21	31	24.9
Thailand (1)	11	11	11.0
Viet Nam (4)	8	18	12.5
Total (12)	**8**	**31**	**19.6**

Values in the parenthesis indicate the number of respondents for each country.

TABLE 13
Duration of fishing per month

Country	Number of days per month		
	Minimum	Maximum	Average
China (7)	15	26	18
Thailand (1)	22	22	22
Viet Nam (5)	15	28	23
Total (13)	**15**	**28**	**20**

Values in the parenthesis indicate the number of respondents for each country.

TABLE 14
Daily catch per boat

Country	Daily catch (kg/boat)		
	Minimum	Maximum	Average
China (8)	1 250	5 000	2 906
Thailand (1)	150	150	150
Viet Nam (4)	12	500	248
Total (13)	**12**	**5 000**	**1 876**

Values in the parenthesis indicate the number of respondents for each country.

middlemen, and only a few sell directly to the market or wholesalers.

The average sale price for trash fish/low-value fish varied between the countries (Table 20). Viet Nam and China, reported the widest ranges in prices. The average price of trash fish/low-value fish was lowest in China followed by Indonesia and highest in Thailand and Viet Nam.

Nearly 85 percent of the households reported that the price of trash fish/low-value fish fluctuated on a seasonal basis. In China, 50 percent of the fishers reported fish prices as stable year round. However, when prices did fluctuate, they did so by nearly 700 percent (between US$0.045 and 0.364/kg, Table 21). A similar degree of fluctuation was noted in Viet Nam. Fish prices were the most stable in Indonesia.

TABLE 15
Revenues from fishing

Country	Revenue (boat/day - local currency)				Revenue (boat/day - US$)		
	Minimum	Maximum	Average	Currency	Minimum	Max	Average
China	50	5 000	2 350	CNY	8	758	356
Thailand	1 500	1 500	1 500	THB	50	50	50
Viet Nam	40 000	2 500 000	946 667	VND	2	139	53

CNY = Chinese Yuan Renminbi; THB = Thai Baht; VND = Vietnamese Dong

TABLE 16
Fisher households selling trash fish/low-value fish to fish farms

Country	Number of fisher households	
	Number	Percentage
China	2	10
Indonesia	6	75
Thailand	12	60
Viet Nam	3	7
Total	**23**	**25**

TABLE 17
Fisher households selling trash fish/low-value fish to the same farm

Country	Number of households		
	No	Yes	Total
China	1	1	2
Indonesia	3	3	6
Thailand	1	11	12
Viet Nam	3	0	3
Total	**8**	**15**	**23**

TABLE18

Fisher households selling trash fish/low-value fish at predetermined prices

Country	Number of households		
	No	Yes	Total
China	2	0	2
Indonesia	5	1	6
Thailand	6	6	12
Viet Nam	3	0	3
Total	**16**	**7**	**23**

TABLE 19

Sales outlets for trash fish/low-value fish

Country	Number and type of outlets		
	Market	Wholesaler	Middleman
China	1	1	15
Indonesia	0	0	12
Thailand	2	0	4
Viet Nam	3	2	12
Total	**6**	**3**	**33**

TABLE 20

Sales prices for trash fish/low-value fish

Country	Sales price (US$/kg)		
	Minimum	Maximum	Average
China	0.061	0.303	0.183
Indonesia	0.222	0.222	0.222
Thailand	0.267	0.500	0.329
Viet Nam	0.139	0.833	0.323

TABLE 21

Variations in the sales price of trash fish/ low-value fish

Country	Sales price (US$/kg)	
	Minimum	Maximum
China	0.045	0.364
Indonesia	0.167	0.333
Thailand	0.167	0.833
Viet Nam	0.056	0.667

Tables 22 summarizes the value of trash fish/low-value fish. The range of species caught was found to be the most diverse in the Vietnamese catches, with the least diversity being recorded in the Thai catches. It was established that some species (e.g. *Sardinella* spp., scad) could fetch either high or low prices.

TABLE 22

Highest and lowest value trash fish/low-value fish species commonly used in cage farming in four countries

Highest value species	Lowest value species
China	
Herring	Golden scad
Sea barbell	Lancelet
Sardine	Mackerel scad
	Sea barbell
Indonesia	
Blood snapper, *Lutjanus sangueneus*	Common ponyfish, *Leiognathus equulus*
Kuniran, *Upeneus tragula*	
Jack, *Caranx melampygus*	Ornate threadfin bream, *Nemipterus hexodon*
Squid	
Thailand	
Mulgil sp.	*Leiognathus* sp.
Rastrelliger sp.	*Sadinella* sp.
Sadinella sp.	
Selar sp.	
Viet Nam	
Anchovy	Flat head
Lizard fish	Pony fish
Mackerel	Red eye
Red big eye	Sardine
Scad	Scad
Sea horse	Small scad
Shrimp	
Squid	

Of 83 respondents, 51 (61 percent) reported that fishing for trash fish/low-value fish earned them a higher income than other activities (see Table 30 for alternative income generating activities). In contrast, 12 (14 percent) of the respondents indicated that other activities provided them with higher incomes (Table 23). Fishers in China either did not own land, or did not report that they owned or rented land that could be used for agricultural activities (Table 24). In contrast, households in Thailand undertook more activities on the land that they owned, rented or leased. Apart from common farming activities such as producing cash or fruit crops, all the households in Thailand reported having fish farms. In general, the most popular activity was growing cash crops (Table 25).

TABLE 23
A comparison between trash fish/low-value fish supply as an income generating activity versus other income generating activities

Country	Trash fish/low-value fish supply vs. other income generating activities			
	About the same	Overall better	Overall worse	Total
China	2	16	2	20
Indonesia	3	5		8
Thailand	8	7	5	20
Viet Nam	7	23	5	35
Total	**20**	**51**	**12**	**83**

b. Agriculture

TABLE 24
Number of fisher households that own or rent land for agricultural purposes

Country	Number of fisher households that own/rent land		
	No	Yes	Total
China	20	0	20
Indonesia	7	1	8
Thailand	9	11	20
Viet Nam	33	10	43
Total	**69**	**22**	**91**

TABLE 25
Land use patterns by fisher households

Country and land use	Number of fisher households
China	**1**
Cash crops	1
Indonesia	1
Cash crops	1
Thailand	**12**
Cash crops	5
Fruits	1
Grouper farm	1
Shed for trash fish storage and supply	4
Shrimp farm	1
Viet Nam	**6**
Cash crops	4
Fruits	1
Vegetables	1
Total	**20**

TABLE 26
Number of fisher households practicing aquaculture

Country	Number of fisher households		
	No	Yes	Total
China	19	1	20
Indonesia	8	0	8
Thailand	0	12	20
Viet Nam	8	7	43
All	**36**	**20**	**91**

TABLE 27
Annual incomes derived from aquaculture

Country	Annual incomes (US$)		
	Minimum	Maximum	Average
China (0)	-	-	-
Indonesia (0)	-	-	-
Thailand (10)	333	10 000	2 877
Viet Nam (7)	56	5 556	3 024

Values in the parenthesis indicate the number of respondents for each country.

TABLE 28
Contribution from aquaculture to household annual incomes

Country	Percent contribution		
	Minimum	Maximum	Average
China	-	-	-
Indonesia	-	-	-
Thailand (10)	30	90	54.0
Viet Nam (6)	12	80	51.1

Values in the parenthesis indicate the number of respondents for each country.

TABLE 29
Non-agricultural income generating activities by fisher households

Country	Number of fisher households		
	No	Yes	Total
China	18	2	20
Indonesia	5	3	8
Thailand	13	7	20
Viet Nam	28	15	43
Total	**64**	**27**	**91**

c. Aquaculture

In Thailand and Viet Nam, mean annual household income derived from aquaculture was US$2 877 and US$3 024 respectively (Table 27). In some households, the income generated from aquaculture accounted for almost 90 percent of the total household income. However, on average, aquaculture accounted for 54 and 51 percent of household incomes in Thailand and Viet Nam respectively (Table 28).

d. Other (non-farm and non-fishing) income generating activities

Nearly 30 percent of the 91 fisher households surveyed were engaged in some form of non-agricultural income generating activity (Table 29). At 43 percent, Viet Nam recorded the highest number of households involved in non-agricultural activities. In contrast, China recorded the lowest level of non-agricultural activities with only 10 percent of households reporting an alternative income source. The reported activities ranged widely, from running a convenience store to house construction, and included skilled work such as being an electrician. On average, the contribution to households' incomes from these activities were 70.0 percent, 36.7 percent, 67.1 percent and 19.0 percent for China, Indonesia, Thailand and Viet Nam, respectively (Table 30). The small sample sizes from China (1) and Indonesia (3) could bias these results. However, it could reflect the true situation in China where fishers were commercial fishermen and did not own land. In this regard, fishing earns them a fairly good annual income, averaging US$3 744.

(ii) Household assets

One household from Indonesia reported having 20 heads of cattle, whereas four Vietnamese households reported having ten, eight, one, and two 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 (Table 31). Across the four countries 82 percent of the fishers reported owning the house in which they lived (Table 32). The type of houses that were owned were durable, and of brick and concrete.

The households owned a range of productive assets and consumer goods. These ranged from aquaculture equipment to televisions, radios, and other white goods. While nearly every household reported having a television and a telephone, vehicle ownership was rare.

TABLE 30
Contribution of non-agricultural activities to household incomes of fishers

Country/non-agricultural activity	Percent contribution		
	Min	Max	Average
China	**70**	**70**	**70.0**
Convenience store	70	70	70.0
Indonesia	**20**	**60**	**36.7**
Automobile shop	60	60	60.0
Convenience store	20	30	25.0
Thailand	**20**	**100**	**67.1**
Business	30	30	30.0
Convenience store	20	20	20.0
Traditional cigarette wrapped with nepa leaves	20	20	20.0
Trash fish supply	100	100	100.0
Viet Nam		**50**	**19.0**
Business	10	25	16.0
Electrician	NA	NA	NA
Fish noodle	35	35	35.0
Fish selling		25	17.5
House constructor	25	25	25.0
Making nets	10	10	10.0
Mechanics	15	15	15.0
Pharmacy	50	50	50.0
Sea food selling	20	30	26.7
Total	**3**	**100**	–

2.2 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, the number was nine. The organisations in Thailand were diverse and included NGOs, whereas in Viet Nam, all 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.

TABLE 31
Number of fisher households raising kivestock and poultry

Country	Number of households		
	No	Yes	Total
China	20		20
Indonesia	7	1	8
Thailand	18	2	20
Viet Nam	30	13	43
Total	**75**	**16**	**91**

TABLE 32
Home ownership by fisher households

Country	Number of households reporting home ownership		
	No	Yes	Total
China	3	17	20
Indonesia		8	8
Thailand	4	16	20
Viet Nam	2	41	43
Total	**9**	**82**	**91**

2.3 Household decision-making livelihood strategies

Household decision-making livelihood strategies provide an indication of how individuals can cope with risks and uncertainties. The survey focused on savings and borrowing. Across all the study countries, 67 percent of the fisher households reported saving money on a regular basis. The lowest rate of saving was in China, where only 5 percent of fishers reported saving money.

In contrast, 85 and 88 percent of the respective fisher households in Thailand and Viet Nam saved money.

Bank savings and jewellery were the main forms of saving. On average, these accounted for 71 percent of saving across all the study countries. In Thailand and Viet Nam these two forms of saving accounted for 84 and 80 percent of savings respectively. One interviewee indicated that he saved for retirement.

Across the four countries, nearly 75 percent of the households reported borrowing money, the highest rate of borrowing was in China where 90 percent of households borrowed money. The lowest rate of borrowing was in Thailand where 55 percent of households reported borrowing money. It is interesting to note that while the annual household income was highest in China (Tables 6– 9), the Chinese appear to borrow more than their regional counterparts. While banks provided the majority of the loans, there were other sources of loans available to the households. For example, in China and Viet Nam, private lenders were the primary source of loans. Only one village fund was reported to supply loans. This fund was in Indonesia.

2.4 Decision factors

(i) Factors that influenced whether a household engaged in fishing and fish supply

Nine factors that influenced a households' decision to engage in fishing and supplying fish were assessed. The most influential factor was ranked 1 and the least was ranked 6. The factors that were assessed were:

1. The ease of access to the fisheries resources;
2. A good market for trash fish/low-value fish (high and stable demand);
3. The ease of undertaking the activity;
4. The degree of compatibility with other income generating activities (flexibility offered to the household by undertaking the activity);
5. The level of household and personal assets (e.g. boat ownership, savings);
6. The possibility to obtain credit (e.g. to purchase a boat, nets and other materials);
7. Whether a neighbour was involved in fishing and fish sales activities;
8. The anticipated financial benefits to the household; and
9. Whether the whole family could contribute to the activity.

Overall and across the countries, the respondents gave the highest ranking to "ease 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 deciding whether to enter the sector.

For convenience in interpreting the ranking information for each of the nine factors, only the number of responses ranked 1 to 10 were considered. The summary results are provided in Figure 3.

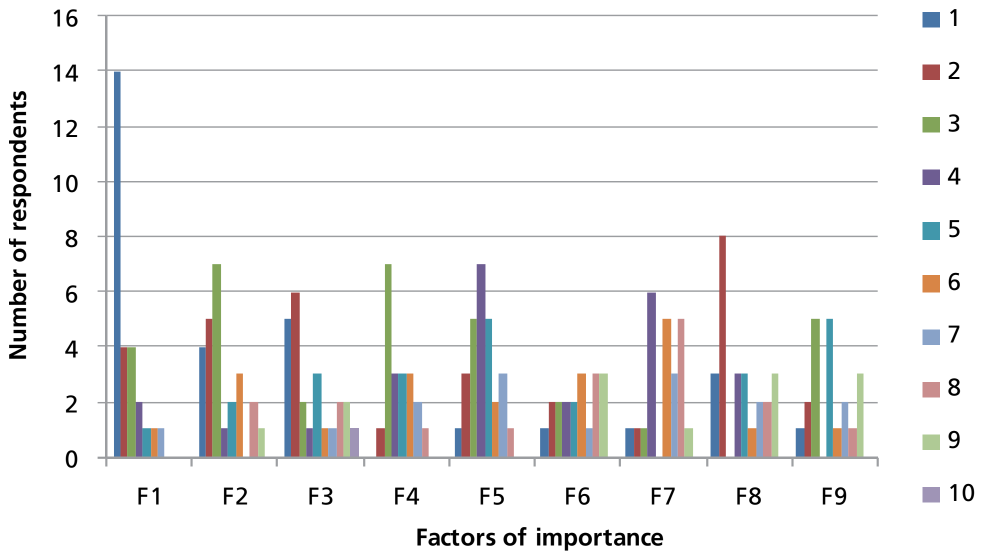
Notwithstanding the first three factors, *viz*., 1) easy access to fisheries resources, (2) good market for the trash fish/low-value fish (high and stable demand), and (3) the ease of undertaking the activity; the fishers considered the remaining factors to be less important. On the other hand, if one considered the cumulative number of responses (ranked 1 to 5) to each of the factors, every factor except perhaps F6 (the possibility to obtain credit) was important. Market accessibility ranked third in importance.

(ii) How fisher households would respond to unforeseen financial difficulties

The fishers were asked how they would respond to unforeseen financial difficulties. They were presented with a number of strategies to overcome these difficulties, and asked to rank them accordingly. The strategies were:

1. Borrow money;
2. Sell household assets;

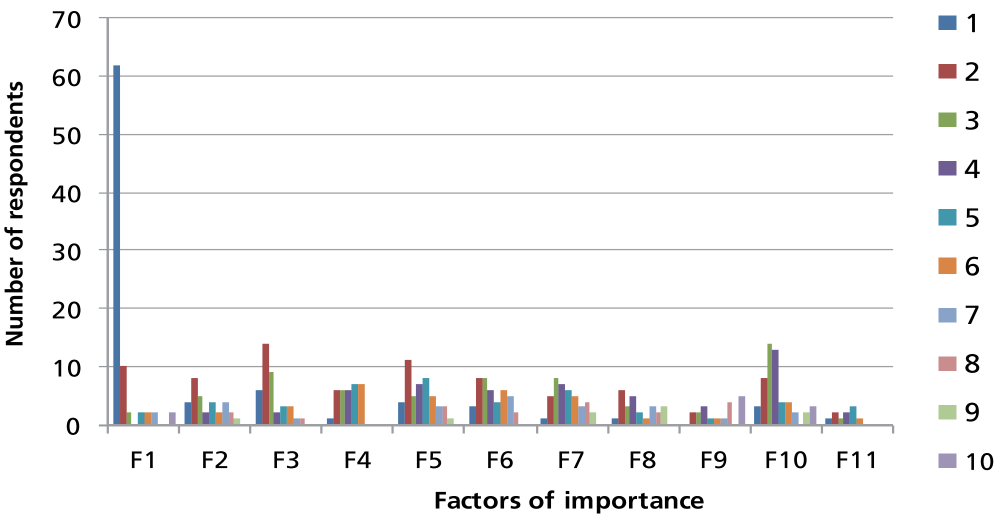
FIGURE 3
Fishers' ranking (1 to 10) of the factors that influenced whether a household engaged in fishing



3. Fish more intensively;
4. Go further out to sea or migrate to other fishing grounds;
5. Stop fishing;
6. Look for non-fishing work in the community or elsewhere;
7. Reduce hired staff for agriculture operations - if agriculture was practiced;
8. Request the family to help with their aquaculture operations;
9. Take the children out of school;
10. Reduce household expenses and number of meals taken; and
11. Alternative actions.

The results are presented in Figure 4. Borrowing money was the overwhelming approach that households would use to tide them over a difficult financial situation. The remaining options were deemed relatively unimportant.

FIGURE 4
Fishers' ranking (1 to 10) of the strategies that households would adopt to respond to financial difficulties



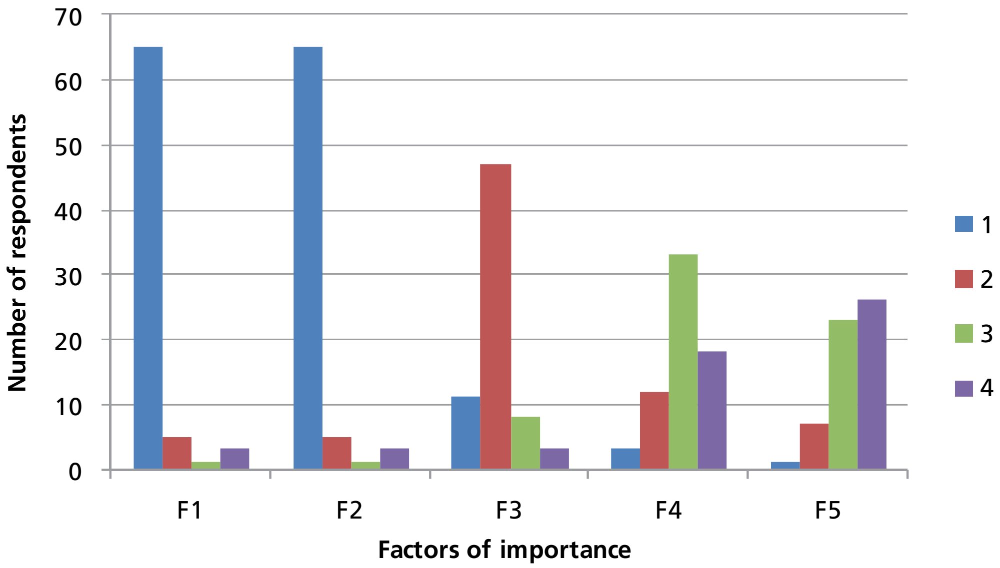
(iii) How fisher households would prepare for the future

The fishers were asked how they would prepare for the future. The factors that they were asked to consider and rank were:

1. Children's education;
2. Continuous saving including contributions to a pension scheme;
3. Simultaneous pursuit of several income generating activities as part of a diversification strategy;
4. Emphasis on subsistence activities for home use/consumption; and
5. Others.

The results are presented in Figure 5. The fishers placed the most emphasis on ensuring that their children were educated. In terms of preparing for their future well-being, maintaining continuous savings including contributions to a pension scheme were considered of paramount importance. A significant number of households also thought that the simultaneous pursuit of several income generating activities as part of a diversification strategy was important as a means of preparing for the future.

FIGURE 5
Fishers' ranking (1 to 4) of the factors that influence their approach to ensuring future prosperity



3. OBSERVATIONS AND CONCLUSIONS

The survey was extensive. The questionnaire included 20 major questions, each requiring a number of responses, making the interview a lengthy process, and possibly exhausting to the respondent and interviewer alike. This was reflected by the diminishing number and degree of responses to the latter questions in the questionnaire. Notwithstanding these limitations, the results are illuminating in respect to the activities that the fisher households are engaged in when supplying fish to the growing marine cage finfish farming sector.

Across the study countries, there are basic differences between fisher households. In China, the sector is best characterized as commercial, using large craft, with fishing being the major if not the sole source of household income. Obviously, as a commercial scale activity, it generates considerably higher incomes to the Chinese fisher households than those of the fishers in the other countries. In contrast, fisher households in Indonesia, Thailand and Viet Nam supplement their household incomes by engaging in a diverse number of activities including agriculture, fish farming, and non-farm activities. In some instances, these alternative occupations earned the household a higher income than that accrued from fishing. The alternative livelihood activities that were reported included crop and livestock farming, which required land to be leased or owned. In this regard, most of the Chinese fisher households did not have access to a piece of land (apart from their dwellings), and would therefore have had no opportunity to engage in these activities. In Thailand and Viet Nam, fisher households owned or leased land. This enabled them to earn income from alternative agricultural activities such as growing cash crops, raising poultry, livestock, and pond aquaculture.

Surprisingly, fisher households did not consider the aspects related to marketing as an important element of their livelihoods. There are two possible factors that could explain this finding. Firstly, there is a stable market for trash fish/low-value fish in terms of sales to either fish farmers or the fishmeal processors, and secondly, the demand for fish products is greater than the supply. To conclude, fisher households overwhelmingly considered their children's education and the accumulation of savings as important in ensuring a comfortable future.

3.1 Changes in perceptions and attitudes to pellet feed

The qualitative assessment of the changes in perceptions and attitudes of fishers and fish cage farmers before and after the trial was undertaken through individual and group discussions, and is summarized in Table 33.

The most prevalent pre-trial belief was that grouper could not be grown on pellet feeds. The trials demonstrated that there were no noticeable differences in growth rates between fish fed with pellets or trash fish/low-value fish. This result showed the farmers that it was possible to grow as well as wean groupers on pellet feeds. This changed the farmers' perceptions of pellet feeds, and subsequently, they started to focus their concern on the lack of suitable feed, and feed access issues - either in terms of the capital required to purchase the feeds or the unavailability of the feed in the market. Concerns about the suitability of the feed in terms of its suitability for the culture species and the size or growth stage of the cultured stock were commonly expressed. The cost of the feed against the anticipated returns was also raised as an issue. The perception persisted that profitability would be lower when pellets were used, likely because of the higher cost associated with the pellet feeds. Other issues related to the use of pellets included convenience of use and the lower incidence of disease that was reported when they were used. One Thai seabass farmer's pre-trial doubts about the suitability of pellets for seabass culture illustrates not the farmers' lack of awareness of the issues related to the use of pellet feeds, but rather the easy access to trash fish/low-value fish and the relative difficulties in accessing pellet feeds.

The idea of the farmers being organized or properly organized was a useful finding from the project. The narrow but pragmatic purpose of their wanting to organize was to increase their leverage in terms of accessing credit and the bulk purchase of feed at a discount. These are good entry points for expanding the benefits that being associated would bring to the farmers.

3.2 Perceptions and outlooks of fishers and traders of low-value fish

The perspectives of fishers, fish traders and a woman cage culturist whose family fishes for food fish and uses the low-value fish and bycatch as feed are described. Synopses of the interviews are presented in a narrative form.

(i) China

Perspectives of the fisher groups. The first group of fishers was met in the regional party office in Lezhou, one of the locations of the cage culture trials. The fishers were aware of the on-going feed trials and claimed that should the fish farmers switch to pellet feeds, their livelihoods would be severely impacted. More than 10 000 pair trawling

Discussion with a cage farmer, Nha Trang Bay, Viet Nam during the project follow-up mission in July 2011.

Courtesy of FAO/Patrick White

Discussion with a cage farmer, Phang Nga Bay, Thailand during the project follow-up mission in July 2011

Courtesy of FAO/Jiansan Jia

TABLE 33
A qualitative assessment of changes in perceptions and attitudes of fishers and fish cage farmers before and after the trial

At the beginning of the project	At the end of the project
China	
Groupers cannot be grown on pellets. Although pellets are used when trash fish/low-value fish is in short supply. It may be possible to grow snappers on pellets. If farmers could raise fish on pellets, marketing would not a problem - even if the taste of the fish is a little different. Fishers viewed farmers switching to pellets as having a severe impact on their livelihoods. Their concern was that the fishmeal factories do not give competitive prices and their payment is usually delayed; there was a belief that the Government should consider the implications to fishers' livelihoods before promoting pellet feeds; as large amount of fish were traded, many people involved in the trade would be affected.	The growth results indicate that it is possible to grow both groupers and snappers on pellet feeds. Feed manufacturers must improve the feed quality to obtain similar growth to that attained when feeding trash fish. Adverse weather conditions affected the outcome of the trials. However, the results provided evidence that the fish could be grown on pellet feeds. Fishers, learning of the results of growing groupers and snappers on pellet feeds, thought a switch would negatively affect their livelihoods and called on the Government to consider providing support to the fisher community. This was the first time farmers had seen such a comprehensive trial, comprising all aspects of water quality, feed analysis, measuring growth, disease monitoring, and livelihood assessments. The project had a positive impact on the fish farmers. If the feed companies improved feed quality they would switch completely to pellet feeds.
Indonesia	
Based on past experience, groupers cannot be grown on pellets. Only early life stages can be fed on pellets. If pellets are fed to the larger fish, there will be a reduction in growth. There are several uses for the trash fish/low-value fish and hence the fishers were not worried about farmers changing from trash fish to pellet feeds. In the event of a change in feed choice, the fishers indicated that there would not be any difficulty in selling their trash fish/low-value fish. Farmers' organizations do not provide the necessary support to the farmers. Marketing is always undertaken by middlemen. Credit is a major problem; unless banks come forward to support the sector, it may not possible to expand the activity any further Women can't participate in cage culture – this is due to cultural issues and safety.	The results did not clearly demonstrate the superiority of pellets over the use of trash fish/low-value fish, but for the first time the farmers have seen grouper being grown to marketable size using pellet feeds. If the feed manufacturers improve feed quality, the culture of groupers on pellet feeds may become a reality. The cost of pellets is a major deterrent to their use. At present, it will not be possible to make a profit with the existing feed conversion ratios obtained using the pellets. The problem of disease appears to diminish when pellet feeds are used - although the fish were not totally free of disease. Farmers met at the end of the trials, and are pinning their hopes on the organization and the newly elected president who made a trip to China (for the final stakeholders' workshop) and may "bring back new ideas".
Thailand	
1. Groupers cannot be grown on pellets. However, the farmers believed that pellets can be used at times when there are no trash fish/low-value fish available. 2. Barramundi culture may be possible using pellets, but growing them on pellets is not economically viable.	The results have shown the possibility of growing barramundi on pellets; when compared to using trash fish/low-value fish, the growth has been impressive. It is economically viable to use the pellet feeds. Farmers were happy with the growth performance attained by the groupers fed the pellet feeds. Though the growth difference is minimal between pellet and trash fish/low-value fish, farmers believed that it was possible to use pellets because of its many advantages. Farmers continue to use trash fish/low-value fish as it is available and cheap. Those farmers that have problems employing sufficient labour have switched to pellet feeds.
Viet Nam	
Growing marine finfish on pellet feeds to market size is not possible. However, on television, they had have seen that some species are grown on pellet feeds in other countries. The taste of the fish that are fed pellet feeds may not be as good as when they are fed with trash fish/low-value fish. Collecting trash fish/low-value fish and transporting it is a problem. Uncertain weather raises many problems in cage management. Fishers were not organized but they recognized the value of being associated and had selected a leader and a vice leader to conduct the trials. Fishers were not worried about a change in the feeding practice of the cage farmers; they have other markets for their catch.	Farmers were impressed with the good growth that was attained using the pellet feeds. As the cost of the feed was unknown, they were unsure (even with a good growth rate) whether they would make money using the pellet feeds. There is so much demand for fish, the fishers said they faced no problems in selling their fish – even in the event that the cage farmers no longer bought their fish. Using pellets is simple, reduces the work load and the problems related to feed preparation and availability. Farmers are now organizing into an association. Farmers would like feed companies to make the price of pellet feeds affordable.

boats were involved in fishing for low-value fish. At present, boat owners enjoy a fuel subsidy, and most boats use 450 horsepower engines. Fishing was primarily undertaken in the Tonkin bay. Pair trawling targets benthic fish and the silt that is drawn into the nets during the trawls results in poor quality catches. About 20 percent of the catch is sold as food fish. Due to the mud that is trawled up, the quality of the lower value fish that is sold to the cage culture operators is poor, and the fish tends to deteriorate quickly. Depending on the quality, the market price varies between US$0.15–0.30/kg. While the low-value fish marketing chain invariably includes middlemen, the fishmeal factories in the area purchase the fish at a lower price than the cage farmers.

The fishers claimed they were unable to change their fishing methods (i.e. bottom trawling) to a technique that would avoid hauling up mud with the fish, and that the pelagic stocks had been fished down in their traditional fishing grounds. The major target fish was therefore the demersal ribbon fish which were still fairly abundant.

In previous years, the low-value fish that was caught was dried, salted and sold as food, particularly to the inland areas. With China's transition to a market economy and the rise in household incomes, there have been considerable changes in food habits and preferences. These changes have resulted in a greatly reduced demand for salted fish.

Should demand from cage culture farmers cease, the fishers could still sell their low-value fish to the fishmeal factories, albeit at lower prices. There are several fishmeal factories in the area, and thus the market for low-value fish in itself was not an issue. This information contrasts with the fishers' claims that a switch to pellet feeds would "severely" affect their livelihoods. However, this perceived impact on their livelihoods could have referred to the reduction in income from the lower selling price of their fish. If the demand from fish farmers for low-value fish ceases, they fear that the fishmeal factories would take the opportunity to reduce the prices that they offered for the fish.

The fishers welcomed the pension plan that has been introduced by the Government. While the details of these plans were not available to the study, the scheme clearly offers some form of security to fishers and farmers who are in effect self-employed. The retirement age is 55 years for women and 60 for men. On retirement, they start to receive a pension.

None of the fishers wanted their children to become fishers. They are acutely aware that the resources are in decline, and feel that the future will be fraught with uncertainties. They see a future in which there will be no more low-value fish to be caught.

Women fish using small boats. When they work on the large boats, their responsibility is primarily to prepare the food for the crew.

The second group of fishers that were interviewed came from Qushui Port. The group included boat owners. This group harboured similar fears as the previous group - that a change to pellet feeds could have serious consequences on their livelihoods. Again these fears were attributed to the high price differential being paid by the fish farmers and the fishmeal producers. Currently, they indicated that they were only able to continue fishing as a result of the fuel subsidy, and they indicated that only 20 percent of their catch was food grade.

Perspectives of a fisher. One fisher was interviewed in depth. Mr Yang Sheang began fishing when he was 19 years old, and has been fishing for 30 years. His sons are also involved in the fishing industry. He owns a 600 hp boat and employs ten crew members. His wife goes out on the boat and prepares the food for the crew. With each fishing trip lasting a week, a good catch of food fish would be profitable. Otherwise on every trip, they reported losing money. As a pair trawler, they share their revenue with the other trawler, and when the quality or type of fish is only suitable for fishmeal, they lose money.

For six months a year they do not fish. This is due to the numerous holidays and the lunar phases. Meeting household necessities when there is no fishing is very hard, and particularly so for the crew members. They have no land to cultivate, and have to find alternative employment to earn an income when they are not able to fish.

(ii) Indonesia

Low-value fish that is caught as a bycatch from the commercial fishing operations comprises a large part of the feed fish that is used by the cage farmers. Discussion with fishing vessel owners, workers, and fish traders indicated that there would be no difficulty to sell the catch for human consumption or to the fishmeal factories. As the fishmeal factories usually pay late, they prefer to sell fish to the cage farmers.

There is no closed season for fishing, however the country has banned certain types of fishing gears, such as trawl nets.

Perspectives of a low-value fish supplier (middleman). Mr Uddin is a young 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 a 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. When 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.

Perspectives of the fishers. To gain an almost first-hand experience of the fishing practices adopted, a group of fishers in Lampung were met on their boat. The boat was powered by a 116 hp inboard engine and had a crew of 10 to 15. 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 had been good. The fishers were confident that if the farmers switched to pellet feed, it would not have any effect on their incomes. They indicated 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, however the farmers pay cash on delivery.

Perspectives of a low-value fish supplier and the former captain of a fishing vessel. Forty-four year old Dono Tariono has been the captain of a fishing vessel, but as it was always a loss-making enterprise, he switched to the low-value fish trade. He collects an average of 150–200 kg 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. He earns a small profit and feels that he has a good job. 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. She feels that feeding low-value fish to grouper is better than feeding them to human beings as people have many alternative food choices, including a variety of fish species.

(iii) Thailand

Impact on livelihoods. 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.

Perspectives of a fish farming family. Mrs Somrit's family took up cage farming after the 2004 tsunami. Before the tsunami the family was engaged in fishing. The family now operates 52 cage units of 3 x 3 x 1.5 m. They raise barramundi, grouper and trevally.

The groupers are grown for over a year. Over this time they attain a weight of one kilogram. At the time of the visit, the farmers had market sized fish. However at the time the local demand for fish was poor as it was not the tourist season. As a result, they were maintaining the fish in the cages. They had no concept of food conversion ratios, and fed their fish to satiation.

Seabass 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 700–800 g, 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. The daughter and son-in law go out fishing everyday and deliver the low-value fish to the farm. In turn, the parents help to maintaining 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 US$0.33–0.4/kg.

The family's main source of income is derived from cage culture. The farm is not insured, and thus any natural disaster or an event that affects production would severely impact their livelihoods. In 2004, the farm was affected by the tsunami, and while they received some assistance, the rebuilding of the enterprise was only made possible by using their savings and the help of relatives. As her husband had no time for the project workshop, Mrs Somrit attended the workshop and decided to undertake the trial.

The farm serves as a technology training centre in the area.

(iv) Viet Nam

In Viet Nam, most of the low-value fish that is available come from the bycatch of commercial fishing boats. The fishers reported that they 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 for making fish sauce.

The perspectives 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 metres) that are powered by 60–70hp 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 US$0.17–0.39/kg, and the food fish is sold for US$1.12–1.68/kg. 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, for this reason, 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.

Women involvement in fishing and their status. In Viet Nam women are not allowed to go on the fishing boats as there is a belief that this will bring bad luck. Furthermore, compared to the Chinese trawlers, the boats are small, and even if this belief changes, it would be difficult for women to find a space on the vessel.

When the fishers were shown a picture that described the multiplicity of household and farm work that women are involved with in South Asia, their response was that the status of women in Viet Nam is different.

3.3 Issues related to the changes in perceptions and attitudes

Between 7 June and 23 July 2011, follow-up missions were undertaken to Indonesia, Viet Nam and Thailand.

The common or dominant issues that were raised in the three countries were:

- The increasing cost and the diminishing supply of trash fish - this has increased the farmers' interest in using pellet feeds.
- There was a lingering perception that in contrast to feeding low-value fish, pellet feeds resulted in poorer growth performance. However, there was a willingness to adopt pellet feeds, even when constrained by supply issues, and the lack of species- and growth stage- specific formulations.
- The capital outlays required to use pellet feeds is high, and farmers often do not have access to credit. This means that the farmers are forced to use low-value fish which is paid for on a daily basis, and does not require access to large sums of capital.
- The current low feed volumes that would be required for the sector does not present a profitable opportunity for the feed manufacturers. This is particularly so for the grouper species, the exception being the humpback grouper in Indonesia. One opportunity that could be explored would be to supplement the protein and lipid content of the existing feeds with products that the farmers can readily access.
- The famers would like to grow the higher value species, but inadequate supply and the poor quality of the seed that is available constrain the transition to pellet feeds. A larger production volume and continuous cropping would likely encourage farmers to adopt the more convenient, labour- and time-saving pellet feeds. This would increase the demand for pellet feeds, which in turn would

provide the incentive for the feed manufacturers to produce species- specific feed formulations.

Country issues, status and priorities are described in Annex 5.

(i) Implications

The findings of the qualitative assessment of perceptions of farmers before and after the trials, and the follow-up mission provide guidance for policy recommendations and follow-up programmes:

a. The livelihoods and welfare of the fishers and trash fish traders
   - In terms of the sustainability of the fishery resources, fishing capacity in the traditional fishing grounds may have to be reduced. This is particularly pertinent in the Chinese fishing grounds where the fuel subsidy for trawlers needs to be re-examined.
   - On a temporary basis, the closed season deprives fishers of their livelihoods. Alternative on-shore livelihoods need to be identified and developed for fishers and fishing crews. Training and skills development needs to be provided for the new livelihood or employment opportunities.
   - In comparison to low-value fish, food grade fish provides a higher income to fishers. Assistance, even as an initial subsidy, to preserve the quality of fish on board needs to be considered.

b. The transition of the sector to pellet feeds
   - Incentives are needed to encourage the feed manufacturers to formulate and market species- and growth stage-specific feeds.
   - There is a need to improve access to pellet feeds and information needs to be made available to the farmers to convince them of the benefits of using pellet feeds.
   - Reinforcement messages and advice need to be continually provided to those farmers that have adopted the pellet feeds.
   - There is a need to establish a microcredit facility to enable farmers to acquire the capital to purchase pellet feeds.

c. The development of the sector
   - There is a need to provide assistance and appropriate incentives for farmers to organize and professionalize the farmers' associations or clubs.
   - There is a need for better management practice (BMP) guidelines for marine cage culture.
   - There is a need to encourage partnerships between the feed manufacturing companies, public institutions and farmers to promote feed research and development.

ANNEX 4

Report of the final regional stakeholders' workshop[1]

EXECUTIVE SUMMARY

The project terminal workshop was held on 25-28 October 2010 at the Paradise Hill Hotel, Zhuhai, China. It was attended by all the country project coordinators, at least one member of the project monitoring team from each country, farmers selected from each country on the basis of the trial performances, international and regional consultants to the project, and representatives from FAO (Rome and Bangkok) and NACA. At the workshop, presentations were made by the consultants for the respective components, the country leaders, and NACA staff on farmer perceptions and a comparison of the country growth trials (four countries / five species). The workshop adopted four basic recommendations in the following broad areas: (i) pellet feeds for mariculture, (ii) trash fish/low-value fish, (iii) better management practices (BMP), and (iv) dissemination of findings.

1. PROJECT RATIONALE, OBJECTIVES AND DELIVERABLES

Over the past decade, marine finfish aquaculture in Asia has been developing rapidly at around 10 percent per annum, and in value terms, at 4 percent per annum of global finfish production. It is the fastest growing aquaculture sub-sector in Asia. Much of this increase in production is attributable to the expanding culture of high-value marine carnivorous species such as groupers. The countries that currently lead marine finfish aquaculture are China, Indonesia, Viet Nam and Thailand, with Korea and Japan not far behind. India is planning major expansion in the sector. The sector is largely dependent on trash fish/low-value fish as the food source of the cultured stocks. The use of trash fish/low-value fish is a contentious issue both from the resource and environmental integrity perspectives, the latter being reflected in the very high conversion rates which imply poor efficiency.

The long term economic viability and environmental integrity of marine finfish aquaculture practices in the region will essentially depend on a shift from the direct use of trash fish/low-value fish to formulated feeds. It is anticipated that this will improve the environmental integrity and economic viability of the farming operations. The problems outlined are common to all the nations involved in marine finfish farming in Asia, and therefore to generate synergies, it is logical to have a regional approach that incorporates farmers.

The project directly involved farmers, and was designed to reduce the perception that fish raised on trash fish/low-value fish perform better than those raised on pellet feeds, and thereby introduce a transition from the use of one feed form to the other. It is envisioned that the adoption of pellet feeds will contribute to the sustainability of the sector in Asia. The outcome of the project was anticipated to result in a reduced dependence on trash fish/low-vale fish (and marine resources) for marine finfish farming in Asia. This would be achieved through a combination of improved feed management practices, and a shift in the sector towards better diets, and particularly the use of formulated diets. This outcome would increase the long term viability of

[1] This annex has been adapted from the Report of the Project Terminal Workshop, November 2010, prepared by NACA.

marine fish farm operations, improve the livelihoods of practitioners, and contribute to poverty alleviation.

The proposal was developed in close collaboration with NACA, FIRA, FIEP, RAPI, and subjected to consultations with stakeholders including the participating countries. The proposal received the letter of support from the Minister of Marine Affairs and Fisheries, Republic of Indonesia, and the Vice Minister of Ministry of Agriculture and Rural Development, Government of Viet Nam. The project was approved by FAO for funding in July 2008. NACA was responsible for the overall coordination.

Among the various components of the project were national and regional stakeholder workshops conducted at the start, during, and towards the end of the project. The proceedings and recommendations of the final regional stakeholders' workshop provide the basis of this report.

2. WORKSHOP PRESENTATIONS

At all times, the technical sessions were conducted in plenary. Each presentation was followed by a question-and-answer session and a general discussion on the presentation topic. The inferences derived from the discussions formed the basis of the recommendations. In the final session, the basic recommendations were presented, reviewed, and a consensus arrived at with respect to the major recommendations. The participants are listed in Annexure A.

3. MAJOR FINDINGS AND INFERENCES OF THE WORKSHOP

a) It was generally agreed that the project has been successful - its major components were completed in time and within budget. All the country trials were completed, and the data collation carried out effectively.
b) The consensus was that the farm trials generally demonstrated the technical feasibility of using pellet feeds to replace trash fish/low-value fish in marine finfish cage culture. Thus, in the long run, pellet feeds provide a viable alternative to trash fish/low-value fish as a feed for marine finfish cage culture.
c) The farm trials showed that in comparison to the direct use of trash fish/low-value fish, the use of pellet feeds achieved similar performance (i.e. growth, survival, food conversion, production and economic benefit) in marine finfish cage culture. However, the results varied between countries. These variations were attributed to the different management practices and culture species that were applied/used in the different countries.
d) The implementation of the project was seen as highly efficient, and that it helped to identify key improvements that need to be made to farming practices. It also brought about much needed cooperation among the farmers, and paved the way for the formation of farmer clusters or small scale farmer groups.
e) It was agreed that the involvement of the private sector (fish farmers, farmer organizations, trash fish suppliers and traders, and feed companies) should be encouraged in future projects of this nature.
f) The workshop agreed that for various technical reasons, the trials conducted in different countries were not strictly comparable. These reasons include species and feed types used, environmental differences between countries and sites, as well as aspects of management by individual farmers. Most of these differences were unquantifiable.
g) The results of the farmer trials have generally changed the perception of farmers that pellet feeds may lead to poor growth and flesh quality. It has been reported that more farmers are shifting from trash fish/low-value fish to pellet feeds in China, and it is likely that farmers in other countries (Thailand, Indonesia and Viet Nam) would follow suit.

h) From the results of the trials, it was concluded that:
   - When fed to any of the culture species, there was no clear indication (statistically significant differences) in the performance of the two feed types.
   - Overall, the trials indicated that in all countries, and with the exception of China, the performance of the fish on the trash fish/low-value fish was slightly better than that attained using the pellet feeds, or in some instances, these differences in performance were hardly discernible (e.g. pompano trials in Viet Nam). All in all, the differences between the two feed types, for any one species, and in each of the countries, were not statistically significant.
   - There were clear indications that some of the traditional perceptions particularly those related to the weaning of wild caught seed onto pellet feeds, or changing from one feed type to the other, were not true. The farmer consultations and stakeholder meetings conducted in the course of the project have enabled the wider dissemination of these observations, which should in time be beneficial to the farming community.

i) It was also observed that:
   - Using pellet feeds was new to the trial farmers, and their inexperience in managing these feeds would have significantly impacted the trial results.
   - In general, management practices (stocking, cage design, feeding management, disease control and other practices) in marine cage fish farming are far from standardized. This often leads to poor results.
   - The uncertainty in production performance, and the many other risks to marine cage culture make cage farmers economically vulnerable. This is probably more so for the small-scale farmers.

j) The environmental assessment component indicated that there were no significant local impacts associated with the use of pellet feeds and/or trash fish/low-value fish - as measured in terms dissolved nutrients (N and P, NH_3), and dissolved oxygen etc. This was attributed to the low stocking density of the cages where the farm trials were conducted. An increase in stocking densities and input levels may have led to different results. The assessment produced the following results:
   - Over time, there were increases in the bacterial loading in trash fish/low-value fish that was stored on ice, as well as an increase in bacterial releases to the culture waters when feeding trash fish/low-value fish that had been stored for 2 or 3 days.
   - It was revealed that the estimated energy cost of producing a kilogram of farmed fish was much lower when trash fish/low-vale fish was used.
   - In general, there was more nutrient leaching to the culture water when using pellet feeds as opposed to trash fish/low-value fish.
   - The need to estimate 'fish in: fish out' ratios for the production of a unit weight of the species under consideration was recommended. This was subsequently carried out, and reported (see Section VI and Annex 2).

k) In general, the pellet feeds that were used in the farm trials were not species-specific and varied in quality. The feed analyses data revealed that some pellet feeds had high moisture and ash contents, which is not desirable. The workshop suggested that the feed analysis data needed to be compared with the specifications provided on the feed packaging.

l) The modes of disseminating the large body of information that was generated from the project, and which is useful to the farmers as well as to other stakeholders (e.g. feed manufacturers, suppliers) were discussed. It was agreed that the modes and channels of information dissemination should be detailed in the recommendations.

m) The workshop noted that there were a range of credit schemes available to the farmers. However, in general there is a lack of recognition of this sub-sector, and particularly the small-scale farmers as being sufficiently worthy of financial assistance. The workshop noted that there had been some recent developments in micro-finance services in many of the countries in the region, and that they could possibly be used to assist the small-scale cage fish farmers. Some countries have introduced micro-credit for small-scale farmers while others, such as Thailand, bundle these loans into small-enterprise assistance programmes. Farmers were unable to obtain insurance. This was likely attributable to the perceived and indeed the actual high risks associated with marine cage farming. It was however noted that the organization of small-scale farmers into groups (clusters, collectives and associations), with legal advice and support, would be a way forward - as is the case for the Indian shrimp farmers. The governments of the participating countries have taken steps to promote the organization of small-scale farmers to improve their bargaining power in marketing, input purchases, and obtaining credit. The success of this exercise has proven that a step-wise evolutionary process to promote the recognition of farmer clusters by different authorities and institutions would lead to the provision of microcredit, cluster certification, and stronger leverage with governmental authorities in obtaining public services and amenities.

4. IDENTIFIED ISSUES AND WORKSHOP RECOMMENDATIONS

4.1 Pellet feeds for mariculture

Issue. 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*), pompano (*Trachinotus blochii*), 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.

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

4.2 Trash fish/low-value fish

Issue. 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 continue to feed trash fish/low-value fish, 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 require large up-front cash payments, and the farmers usually find it easier to afford trash fish/low value fish which can be purchased on a daily basis. Many farmers also fish and either target low-value species or have access to bycatch to meet 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.

Recommendation. The workshop 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**.**

4.3 Better management practices (BMP)

Issue. The workshop noted the benefits that the adoption of BMPs has brought to small-scale farming communities (e.g. shrimp farming in India; catfish farming in the Mekong Delta etc.), and especially when such communities are organised into clusters. The benefits that have been observed include increased productivity, market access, bargaining power (e.g. ability to purchase feed at a discounted rate, to demand seed of a standard quality, and to negotiate better deals with buyers), augmenting the certification of produce (the cluster as whole meeting the cost of the certification of all their farms rather than individual farmers paying for separate certification), and having a stronger voice in the formulation of policy. BMPs for marine finfish culture are however not available. The workshop recognised that some of the findings pertaining to feed types and their management can be used in the development of BMPs for marine cage culture, thereby facilitating the process of their development.

The BMPs could also be modified into technical guidelines for marine cage finfish farming in accordance with the FAO Code of Conduct for Responsible Fisheries[2].

Recommendation. The workshop recommended that BMPs be developed for marine finfish cage farming as a matter of urgency, and that to reap the maximum benefits from the activity, such a development should be linked to the formation of farmer clusters. The BMPs should emphasize resource use, in particular the biological resource use in feed of both types, the economic and environmental impacts of different feed management practices in small-scale marine cage culture in selected countries, and the development of suitable strategies and a set of best protocols for feed management.

The workshop also recognized the lack of technical guidelines for good feed management practices for small-scale farmers, and recommended that technical manuals/guidelines for better feed management practice should be developed and disseminated to farmers. This should be undertaken with the recognition of the need to develop better management practice (BMP) for the entire culture cycle of important marine finfish species.

4.4 Dissemination of findings

Issue. 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 in Thailand had taken the initiative to support the production and dissemination of extension materials prepared by NACA. The information from the growth trials, environmental study, farmers' perception and livelihood analyses, could be disseminated through

[2] FAO. 1995. Code of Conduct for Responsible Fisheries. Rome, FAO. 41 pp.
(also available at: ftp://ftp.fao.org/docrep/fao/005/v9878e/v9878e00.pdf)

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.

Recommendation. 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 and its participation in the preparation of scientific and related publications is encouraged.

The workshop further recommended that FAO take up the initiative to enable relevant stakeholders that participated in the project to legally publish and disseminate the project findings as appropriate.

4.5 Other recommendations

Considering that the cage culture of marine finfish is likely to expand in the near future, there will be a need to move away from inner bay areas to offshore areas, and thus avoid the negative environmental impacts associated with developments in inshore areas. In this regard, the workshop recommended developing guidelines for offshore mariculture incorporating policy, technology and management aspects.

Currently, there are many small-scale farmer groups operating as clusters and organized as clubs making use of the advantages of clustering. This should be encouraged and promoted further using the models developed in Viet Nam and India. 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.

5. CONCLUDING REMARKS

In trials that involved four countries and different culture species, it was not possible to obtain directly comparable and uniform results that have statistical robustness. However, some common findings that are relevant to marine cage culture development in the region, and have possible application elsewhere, emerged from the on-farm trials and through the surveys carried out in the countries. These major findings included:

- grouper (as well as barramundi and snappers) can be weaned from one feed type to the other, within a few days, and without performance losses.
- the farm trials generally demonstrated the technical feasibility of substituting trash fish/low-value fish with pellet feeds, thus making pellet feeds a viable alternative to trash fish/low-value fish; and
- it was demonstrated that the quality of the fish is not impacted by the feed type. However, it would be useful to have flesh quality analysis carried out to consolidate this position.

The trials also brought together the project team and groups of farmers at many stakeholder meetings and consultations. These interactions were useful for both the project team and the farmers, and in many instances, the latter had the opportunity to learn from their counterparts' ideas and practices. These they eventually applied to their farms.

The major issue to determine the comparative efficacy of using trash fish/low-value fish or pellet feeds is not completely resolved as yet. The results of the trials in the different countries indicated that there was significant variability in the performance between both farms and species; however, the relative efficacies of the two feed types applied to the different species were not significant. Understandably, it was apparent that the farmers rarely account for non-monetary variables and opportunity costs in their concept of profitability. Amongst others, these include the time spent for trash fish/low-value fish preparation prior to feeding, potential wastage, the lack of uniformity in the quality and quantity of the supplies of trash fish/low-value fish, storage problems associated with the trash fish/low-value fish, the overall convenience in feed management, and the depreciation of farm assets. An economic analysis that can reasonably take these issues into account would better indicate the real profitability of the enterprise. In this regard, there was consensus across all the countries, and the farmers endorsed the need to include these points in the dissemination of the information from the project.

There was also consensus among stakeholders in all four countries on how and in what forms the findings of the project should be disseminated. Other than the means suggested earlier, much of the scientific findings could be disseminated through FAO technical publications, scientific publications, with abbreviated forms published in semi-technical magazines, and extension materials in the national language.

One of the important features of the project was private sector involvement. Apart from providing pellets free of charges to the trial farmers in Thailand and Viet Nam, the two feed companies involved in the project came forward to take responsibility for the printing and distribution of a poster outlining the pros and cons of using the two feed types. Public awareness and interest in marine cage faming as a whole, and the project in particular can be promoted by enlisting the involvement of the mass media.

ANNEXURE A

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Discussion group leader (from Phang Nga) presenting the Phang Nga group's results during the stakeholders' workshop in Phuket, Thailand, June 2011. Eighteen cage farmers from Krabi. Phang Nga and Phuket, a third of them women, took part in the workshop

Courtesy of FAO/Mohammad Hasan

Discussion in the stakeholders' workshop in Bandar Lampung, Indonesia during the project follow-up mission in July 2011.

Courtesy of FAO/Budi Kurnia

ANNEX 5

Project uptake and future priorities[1]

EXECUTIVE SUMMARY

A three country mission to Indonesia, Thailand and Viet Nam was undertaken sixteen months after the termination of the participatory on-farm trials to compare the efficacy of trash fish/low-value fish vs. compound pellet feed. The mission found that there were variations in the level of uptake of pellet feeds among the cage farmers and across the trial countries. With the strengthening of their aquaclubs, the Vietnamese farmers have begun trying or using pellet feeds. In contrast, Indonesian farmers were hesitant to adopt the trial results for their preferred species, the humpback grouper. The trails in Indonesia were undertaken with brown-marbled grouper (tiger grouper). In Thailand, the farmers indicated that they were experiencing difficulties accessing pellet feeds, and felt that these feeds were expensive. A common issue that was reported by the farmers was the lack of species or size specific pellet feeds. In Indonesia and Thailand, perceptions persist that the use of trash fish results in better growth performance than that achieved using pellet feeds. Nevertheless, there are encouraging developments, in that both trial and non-trial farmers expressed a desire to use pellet feeds, and would use them if they were available. The perception of a diminishing catch in low-value fish and the reality of increasing fish prices have led many farmers to seriously consider switching to pellet feeds - should suitable formulations be available on the market. This change in attitudes shifts the issue towards the commercial viability of producing and marketing pellet formulations for specific species and sizes of fish. The Indonesian findings suggest that there appears to be a business case for developing formulated feeds. Another issue shared by Viet Nam and Thailand was the availability of quality seed. Applying better management practice guidelines are a high priority among all the farmers in the three countries. The current mission has formulated project concepts to address these issues in the three countries.

1. INTRODUCTION

The three-country mission was undertaken 16 months after the termination of the participatory on-farm trials to determine the current status of the marine cage farming industry, the level of knowledge and the uptake of the project trial results, and to identify current issues and needs of the industry. It sought to confirm the recommendations that were made at the end of the project, and further assess the priorities for the sector in line with the objectives of the project[2]. The mission activities comprised:

1. Conducted focus group discussions with the project partners in Lampung (Indonesia), Nha Trang (Viet Nam), and Krabi/Phuket (Thailand), to discuss the findings and conclusions that were derived from their respective case study reports. A particular focus was placed on the farmers' participatory trials.

[1] This annex has been prepared based on the mission reports of Dr Nigel Abery and Mr Pedro Bueno and back to office travel reports of Dr Mohammad Hasan and Mr Jiansan Jia.

[2] The mission was made up of Dr Mohammad Hasan (FAO), Dr Nigel Abery (FAO consultant), Ms Ruth Garcia Gomez (FAO) (Indonesia component), Mr Pedro Bueno (FAO consultant) (Thailand component), Dr Tipparat Pongthanapanich (Kasetsart University) (Thailand component), Mr Jiansan Jia (FAO) (Thailand component). The local project partners in the respective countries that facilitated the meeting with stakeholders are the Lead Centre for Mariculture Development, Indonesia; Research Institute for Aquaculture No. 3, Nha Trang, Viet Nam; Coastal fisheries Research and Development Centres, Phuket and Krabi, Thailand. The period covered was 7 to 23 July 2011.

2. Consulted the project partners to resolve the issues that required attention, and finalised the contents of the final project report.
3. Consulted and discussed the recommendations that were agreed at the terminal workshop with stakeholders. These included discussions with the marine fish cage farmers and trash fish/low-value fish fishers and suppliers in Indonesia, Viet Nam and Thailand.
4. Conducted a rapid survey of farmer management practices. The survey was designed to assess the relevance of the project recommendations.
5. Assessed the short term uptake by trial and non-trial farmers of the project findings and recommendations in the study areas.
6. In consultation with the relevant stakeholders, prepared project proposals that were designed to identify/develop better management practices for small-scale marine cage farming in the countries of the Asia-Pacific region. These proposals included the practicalities of their implementation.
7. Presented the overall findings and conclusions of the project during a focus group discussion in Phuket, Thailand.

2. METHODOLOGY

The mission visited Bandar Lumpung, Indonesia (4 days), Nha Trang, Viet Nam (4 days), and Krabi, Phang Nga and Phuket, Thailand (5 days). The team met with national partners and farmers, and undertook field visits to interview cage culture farmers and hatchery operators (a mud carp farm that uses trash fish was also visited in Nha Trang, Viet Nam). A half-day workshop among the team members was held immediately after the Thailand stakeholders' workshop. The purpose of this team workshop was to synthesize the results and identify priority follow-up projects.

3. RESULTS

3.1 Issues requiring attention in the final report

1) Indonesia

Plankton blooms and water quality were monitored and had a major impact on the trials. However, water quality and phytoplankton protocols, materials or methods were not described in the country report. This was clarified with the project water quality monitoring and analysis team. During the workshop some farmers mentioned partitioning their trash fish (head and tail vs. body), and feeding head and tails to the brown-marbled grouper, and the body part to humpback grouper. The typical trash fish species, modes of feeding, and farmer procurement and preparation techniques were clarified with the project trial farmers.

2) Thailand

As many of the trash fish species have the same local names, the local names were clarified with the species names. Two trial farmers reported using fish processing waste, and more information was obtained about the species composition, source, and their use of this waste. The pellet feed that was used in the grouper trial was changed during the trial. It was established that the change in diet occurred two weeks prior to the termination of the trial, and that the new diet was in fact a sinking cobia pellet. The change in feed occurred in the Phang Nga trial farm.

3) Viet Nam

Modes of trial farmer trash fish procurement and processing were not described in the country report. These issues were clarified with the project trial farmers. In addition, the recommendations listed in the stakeholder report appear to be a repeat of the text from the Indonesian stakeholder's recommendations - this was clarified with the project partners.

4) Cross country information

Information pertaining to transport, processing and storage costs of trash fish/low-value fish was obtained from all three countries. This information, although variable for each individual farmer, can be used to develop an understanding the true cost of using trash fish as a feed.

3.2 Relevance of project recommendations

1) Indonesia

The Indonesian marine cage culture industry stakeholders prioritised their needs as follows:

a. The top priority is for *better quality pellets for the final stages of rearing to be available in the market, and at a good price*. Farmers would switch to pellet feeds if the available feeds were able to match the growth attained using trash fish. Farmers placed a high priority on a pellet that produces high growth rates for large size (>250 g) humpback grouper. The farmers indicated that they would be willing to buy pellet for US$ 2.70–3.80/kg (25 000–35 000 IDR[3]/kg) if the concomitant growth rates matched those attained using trash fish. The next priority was for a pellet that matched the high growth rate that they attain from using trash fish, for large brown-marbled grouper, and cost less than US$ 2.00–2.50/kg. If such a feed could be developed, the farmers indicated that they would switch to the pellet feed. The Main Centre for Mariculture Development (MCMD) has a nutrition section and laboratory, but it does not have the equipment to undertake proximate analysis for protein, lipid, moisture, ash etc., or sufficient technical expertise in fish nutrition to undertake a project of this nature without assistance.
b. The second priority is *for the development of better management practices (feed and health management)*. Farmers reported having issues with very high production costs, disease, and low survival rates. The farmers indicated that they wanted guidelines on advanced grouper production techniques that included disease identification and treatment, feeding and feed management, and stock management techniques. The cage mariculture sector is a relatively new industry and culture practice guidelines are yet to be developed. Although MCMD has a section that covers culture practices, the current activities do not include the development of better management practices for marine cage culture species. The responsible staff would require assistance in the development of such a program.
c. The third priority is the provision of advice on *how to strengthen aquaclubs*. Farmers are having difficulty realising the potential of their aquaclubs, and are facing difficulties in dealing with the local authorities. In this regard, the farmers indicated that they want assistance to strengthen their aquaclubs such that they achieve the desired outcomes. The MCMD does not have sufficient expertise in aquaclub development or related activities to provide this support to the farmers.

2) Thailand

The Thai marine cage culture industry stakeholders prioritised their needs as follows:

a. The top priority is *the development of guidelines on better management practices (BMP) for marine cage farming focusing on feed management*. Applied research to determine the optimal culture practices of grouper species and the development of guidelines for better management practices is required to provide the aquaculture extension staff with the knowledge that they need to instruct the farmers. BMPs are particularly important in Thailand as there have been large numbers of new entrants in to the marine cage culture industry in recent years, and this trend is likely to continue. These new entrants lack the knowledge and skills to culture

[3] 1 US$ = 9 100 Indonesian Rupiah.

groupers efficiently, and are thus operating in a high risk environment. The development and dissemination of better management practice guidelines for the key culture species would significantly reduce the business risk - particularly for new, small-scale entrants. As the highest cost associated with marine cage culture is feed, the development of better feeding and feed management guidelines should be prioritized.

b. The next priority is *the market availability of a good quality feed suitable for grouper species*. Marine finfish cage farmers believe that trash fish is becoming scarcer, and that in future, will become more so, and more expensive. Apart from the increasing demand from aquaculture and other low-value fish users, farmers believe that in the future, environmental and social issues will likely result in further reductions in catches. To prepare for this situation, they believe that a good quality pellet feed suitable for grouper culture is required.
c. An important priority is the *increased availability of fingerlings*. In Thailand, grouper fingerling production is undertaken by large-scale integrated producers, and the government hatcheries. Some fingerlings are imported by the larger operators who sell their excess seed, which the farmers claim are usually of low quality. Large-scale hatcheries produce fingerlings solely to supply their own needs. Small-scale farmers rely on the government produced fingerlings. Over the past two years, there has been an increase in the number of small-scale cage farmers entering the industry. This has increased the demand for grouper fingerlings and resulted in each farmer receiving fewer seed to stock than in previous years. The government hatcheries are aware of the increasing demand for fingerlings, and have planned to increase production. It is likely that the shortages in fingerling production will be resolved by the government hatcheries. However, there is a possibility that the demand for fingerlings will continue to increase as more new entrants take up marine cage culture. Fingerling production and supply should therefore be reviewed in near future for sustainability of this sector.
d. Farmers expressed the need for *increased access to credit*. Currently, a limited amount of credit, such as the village fund is available; however, the amount that each individual can borrow is small. Farmers have access to other sources of credit, the amount being based on the individual farmer's circumstances - such as value of assets owned. Farmers believe that access to larger amount of credit would allow them to expand their businesses and improve profits.

3) Viet Nam

Vietnamese marine cage culture industry stakeholders prioritised their needs as follows:

a. Top priority is *better management practices for marine cage farming focusing on feed management*. Farmers lack sufficient information and knowledge about management practices for marine cage culture, and specifically, the efficient use of feed and feeding practices. Farmers are concerned about the increasing costs of production. Currently, feed represents the single largest production cost, and farmers are unsure of the most appropriate way to feed trash fish/low-value fish or pellets. In addition, they generally feed to satiation which results in overfeeding. Guidelines on appropriate stock management and feeding rates that maximise economic efficiencies will increase the profitability of their operations and promote environmental sustainability.
b. The second priority is the development of *high quality feeds for large cobia and lobster production*. The main species currently cultured (lobsters and cobia) use trash fish/low-value fish, and at present, there are no suitable pellet feed available for the larger cobia, and for the lobster grow-out cycle. In Viet Nam, larger pellets that are suitable for cobia are not available in the market - the industrial demand

is currently too low to warrant commercial production. It is likely that if cobia farmers are trained to use pellets efficiently, and are provided with appropriate pellets so that they can observe their efficacy for themselves, they are likely to start using pellets. This would create the market demand conditions that are required to stimulate commercial production.

c. The third priority is to *increase local fingerling supplies through the development of a local "backyard" marine finfish hatchery industry*. This would reduce the reliance on imported fingerlings from Taiwan Province of China (POC). An intervention of this nature could be based around the renovation of 10–20 ex-backyard shrimp hatchery producers, and integrating them with existing broodstock holding and spawning facilities, for example, those facilities that are available at the government hatcheries. In Indonesia, this model proved effective, and could be adapted in Viet Nam.

3.3 An assessment of the uptake of farmers' participatory trial results

1) Indonesia

The uptake of the project findings in Indonesia was limited. Prior to the project, the farmers were already using pellet feeds to culture small grouper (≤250 g), and were feeding trash fish/low-value fish to the larger fish (>250 g). In general, they only fed pellets to the larger fish when disease treatments were required, as it was easier to administer the therapeutics in the pellet feeds as opposed to the trash fish/low-value fish.

After the project, the farmers continued to use their original feeding regimes. While the farmers know that groupers can be cultured throughout the culture cycle using pellet feeds, they maintain the belief that the growth of the large groupers (>250 g) fed with pellets is inferior to that when they are fed trash fish/low-value fish. The trial results demonstrated that overall, the brown-marbled grouper fed trash fish/low-value fish grew more than those fed the pellet feeds, however the difference in growth rates was not significant. Nonetheless, the use of more replicate cages would have yielded a statistically significant difference. Furthermore, the trial in Indonesia was based on the brown-marbled grouper. While some farmers are still growing the brown-marbled grouper, most farmers are now primarily growing the humpback grouper. Some farmers suggested that the results from the trial with the brown-marbled grouper do not apply to the humpback grouper, and that they believed that the growth of the humpback grouper (the preferred culture species of most of the farmers in Lampung), when fed with pellet feeds, was slower than that observed when they were fed with trash fish/low-value fish.

2) Thailand

In Thailand, there was some uptake of the trial results pertaining to barramundi culture, however, this was not the case for the brown-marbled grouper farmers who maintained their original culture practices. In terms of barramundi cultivation, one trial farmer who was not using pellet feeds before the trial reported using pellet feeds after the trial. Others who participated in the trial continued using trash fish/low-value fish. Despite the trial, many farmers including many of the trial farmers, maintain the belief that feeding trash fish/low-value fish produces better growth performance than feeding pellets.

There is a major issue of pellet availability in the Krabi/Phuket/Phang Nha area. In Krabi, there are no feed dealers, however there is a pellet feed being sold in "SuperCheap" (a large store selling many products). However, the pellet feeds are sometimes out of stock. Only a floating barramundi pellet is sold, and at US$ 1.30/kg, some of the farmers consider the price to be too high. The farmers also reported that they preferred to use sinking pellet for grouper culture.

The trial farmer who had been using pellet feeds prior to the trial and continues to use pellets, does so because the costs associated with transporting the trash fish from the landing site are excessive, and sometimes the trash fish/low-value fish is of poor quality, and laced with formalin. This being the case, it is more cost effective to use pellet feeds. The farmer reported purchasing the feed in a store in Krabi, where he goes two or three times a week to deliver fish.

3) Viet Nam

In Viet Nam, there were positive signs of farmers adopting the project findings. Prior to the project, none of the trial farmers was using pellet feeds. However, after the trial, some of the farmers continued to use pellets, whilst others have plans to use pellets when their newly formed aquaclub is in a position to bulk-purchase feed at a discounted price.

Furthermore, farmers who were not involved in the trials are starting to experiment with pellet feeds. As the farmers are all located in aquaculture zones, it is likely that these non-trial farmers have observed the trials, or heard about them from the farmers that were involved in the trials.

Currently, both the trial and non-trial farmers are using pellet feeds that have not been specifically formulated for marine fish. For example, they reported using chicken feed mixed with squid oil or even striped catfish feed. As a result, they are experiencing mixed results. In this regard, one farmer that was using catfish feed reported poor growth, and has recently changed his feed to a marine finfish diet.

3.4 Project proposals

Based on the consultations with the marine cage culture stakeholders in Indonesia, Thailand and Viet Nam, three project concepts have been developed. These cover the key issues that need to be addressed to ensure the sustainable development of the industry in the Asia region. These comprise:

1. Development of a suitable pellet feed for large humpback and brown-marbled grouper

Target beneficiaries

The target beneficiaries of the project are the grouper farmers with additional benefits to farm workers and the pellet feed manufacturing industry. In addition, the reduced demand for trash fish/low-value fish from the grouper farmers will reduce fishing pressure on the fish stocks. In time, the increased availability of feed fish species (low-value fish) in the fishery will likely result in higher yields of the high-value species that are used for human consumption. An improvement in the yield of these fisheries would be of particular benefit to poor communities.

Background

The marine finfish aquaculture industry in Indonesia is a lucrative and fast growing sector. Indonesia is one of the leading producers of cultured marine finfish. Currently, the growth sector is grouper culture, and most notably, the humpback and brown-marbled groupers. These are both high-value species that are almost exclusively produced for the export market. The culture of these species is primary undertaken in small cages (3-6 m in length and width), and in sheltered inshore areas. Both species can be bred and raised in captivity. Currently, the majority of the fingerlings that are used in production are sourced from hatcheries.

The Indonesian marine finfish aquaculture industry is primarily an export orientated industry with the majority of product being exported to Hong Kong SAR of China, mainland China, Taiwan POC and Singapore. Small volumes of fish are also marketed locally for the high-end restaurant trade, for example, to the high-end Chinese restaurants. In Indonesia, grouper aquaculture has been identified as one of the priority areas for development, and according to the 2011 Plan developed by the Directorate General of Aquaculture of the Ministry of Marine Affairs and the Fisheries, a production target of 20 000 tonnes is to be realized by 2014 (MMAF, 2011). To reach this target, a production increase of 31 percent per annum is required.

Issues to be addressed

The main constraint to the expansion of the grouper culture sector is the lack of appropriate pellet feeds. The industry continues to use trash fish/low-value fish as the primary feed source. However, the exploitation of this resource has reached its maximum potential. Trash fish/low-value fish is becoming increasingly scarce, and prices are rising rapidly. In 2002, Indonesia used an estimated 96 134 tonnes of trash fish/low-value fish for aquaculture (Stobutzki *et al*., 2005).

Typically, the industry uses pellets for smaller (≤250 g) fish, and achieves good growth using the current formulations. However, for larger fish (>250 g), the pellets that are available in the market are of inferior quality, and in comparison with trash fish/low-value fish, result in reduced growth. The harvest size for humpback grouper and brown-marbled grouper is 0.4–0.6 kg and 0.5–0.7 kg respectively. As the bulk of the feed that is used in production is consumed by groupers that are more than 250 g in weight, considerable amounts of trash fish/low-value fish is required.

Typically, trash fish/low-value fish is sourced locally, and although it is of a high quality, there are limited supplies and prices continually increase. While the availability of trash fish is limiting the expansion of this sector, and price increases erode profit margins. Clearly, there are concerns that trash fish/low-value fish is becoming scarce, and that the future dependence on trash fish/low-value fish as a feed source is will become unsustainable.

The need to develop suitable commercial pellets for larger fish (>250 g) to replace the trash fish/low-value fish feed was first identified in 2005 (Williams and Rimmer, 2005). The development of a suitable pellet feed for grouper is now an urgent consideration for sector development, and in a 2011 stakeholder meeting for the project "Reducing the dependence on trash fish/low-value fish as a feed for aquaculture of marine finfish in the Asian region", the need to develop a pellet feed was stressed. The farmers have indicated that they would very much like to use pellet feeds throughout the entire grow-out period, but are unable to do so as the diets that are currently available result in inferior growth in the larger groupers. In addition, disease transmission from feeding trash fish/low-value fish to the culture species has been identified as a significant production risk.

The grouper farming industry is small compared to other sectors, however there are still significant feed sales to be made, and a profitable business can be made from the production and sale of pellet feeds for the large groupers. However, feed companies appear to see a high risk in undertaking research and development for specific feed formulations. The reason being that they cannot be sure that they will receive an adequate return on investment.

The following business case for grouper pellet feed production has been developed:

- The maximum price that farmers are willing to pay for a pellet feed that is suitable for brown-marbled grouper = US$2.5/kg.
- The maximum price that farmers are willing to pay for a pellet feed that is suitable for humpback grouper = US$3.5/kg.
- At current production levels of 9 000 tonnes of grouper per annum in Indonesia, and assuming an FCR 1.2, there are potential annual feed sales of US$27 million.
- At Indonesia's 2014 target production level of 20 000 tonnes of grouper a year, this equates to about US$84 million in potential feed sales per annum.

The development of specific diets for grouper will likely lead to improvements to growth rates above those currently achieved using trash fish/low-value fish, lower levels of disease, and greater environmental sustainability.

Objective
To develop grouper pellet feeds that achieve superior growth rates when compared to currently available commercial grouper feeds.

Outputs
Output 1: Current knowledge of grouper nutrition reviewed

Output 2: Feed companies engaged in projects to work in developing pellet feeds

Output 3: Grouper pellet trials
- Theoretical feed formulations
- Manufacture of a small batch of grouper feeds
- On farm trials of different feed formulations

Output 4: Dissemination of feed trial results to the feed companies

Output 5: Promotion of the new pellet feeds for adoption by the grouper farmers

2. Development of better management practices for cage mariculture in Indonesia, Thailand and Viet Nam

Stakeholder analysis and target beneficiaries
The target beneficiaries of the proposed project would be marine cage farmers in Southeast Asia focusing on Indonesia, Thailand and Viet Nam. During the period between 7 June to 23 July 2011, field visits were undertaken and stakeholders' workshops were held with farmers in Indonesia, Thailand and Viet Nam as part of an FAO mission to understand the bottlenecks in the development of sustainable marine cage culture in Southeast Asia. The lack of guidelines of farm management practice for the marine cage culture industry was highlighted as a key constraint to the sustainable development of the industry in Southeast Asia. In the Indian shrimp farming industry, and more recently in the Vietnamese catfish farming industry, the development and improvement of management practice guidelines, through a research program, has been shown to improve the environmental, social and economic sustainability of the industry. The better management practice approach would expect to bring substantial benefits for the marine cage culture industry.

Background
Mariculture in cages in inshore areas is a fast growing industry. The industry is characterized by the culture of a range of high-value species. Some of the important culture species in Indonesia, Viet Nam and Thailand include: humpback grouper, brown-marbled grouper, coral trout grouper, barramundi, snubnose pompano, red snapper, cobia, golden trevally and lobsters. Although marine cage farming is considered to be lucrative sector, the industry is characterised by variable performance levels between farms. In addition, it is coming under pressure from increasing costs, particularly feed, the lack of an adequate and timely supply of fingerlings, and increasing incidences of disease. The industry provides income for small-scale family owned cage culture businesses, and employment and income for larger scale cage culture businesses. The sector is predominantly export orientated with products primarily exported to mainland China, Hong Kong SAR, Taiwan Province of China and Singapore. In this respect, the industry contributes to valuable foreign exchange earnings to these Southeast Asian countries.

Issues to be addressed
The marine cage culture industry is characterised by a wide range of species, environments, culture scales, management practices, and levels of profitability. Feed is

the largest input cost in marine cage culture in Asia, and while poor quality feeds are generally held responsible for aquaculture pollution, poor feed management is often the leading cause of this pollution. The amount of feed that is not consumed by the culture species can be significant, and depends not just on the physical characteristics of the feed, but also on the way that it is fed (New, 1996).

Feeding and feed management is perhaps one of the most critical aspects of farm management - feed represents the highest production cost, and many farmers feed inefficiently. For example, under experimental conditions, food conversion ratios (FCRs) for trash fish/low-value fish are about 3.5:1 (Chua and Teng, 1982; Millamena, 2002). However, under farming conditions, FCRs often vary between 6:1 to 17:1 (Williams and Rimmer, 2005). Furthermore, reported differences in the FCRs between individual farmers indicate that FCRs can be even higher. Clearly, if the FCR under farming condition can be reduced to even approaching 6:1, enormous amounts of trash fish/low-value fish can be conserved.

Due to the variety of species cultured and their different culture requirements, farmers often find it difficult to recognise the species-specific culture requirements, and optimize performance. Considerable feed wastage occurs; without adequate feed guidelines, farmers typically feed to satiation or at an arbitrary ration rate without understanding the implications on performance and profitability. Farmers lack the information, resources, and are adverse to the risk of undertaking their own rigorous trials to determine the efficacy of different feeding methods. Although farmers generally use feeding systems that are based on their own trials, the trials that are undertaken are usually not repeated, and are often stopped once a system is found to work, regardless of whether it is optimized or not.

In addition to the feed composition and the physical properties of the feed, there are species-specific feed management issues that can influence feed efficiency, these include: feed rations, feeding time and frequency, and stocking density. The optimal feed rations, feeding times, and stocking densities have been shown to change with the life stage or size of the fish.

Objectives

To develop better management practices (BMPs) for marine cage culture in Southeast Asia and promote their adoption by the industry. The BMPs aim to increase the economic, environmental and social performance of the marine cage culture industry in Southeast Asia.

Outputs

Output 1: Review the current status of marine cage farming practices in Southeast Asia, focusing on grow-out management practices such as feed use, feeding methodologies, stocking methodologies, but also covering cage siting, cage maintenance, disease treatments, grading, harvesting, and the economics of the farming operations.

Output 2: Farmer participatory trials to improve feed management for each key culture species in Indonesia (humpback grouper and brown-marbled grouper), Thailand (barramundi, brown-marbled grouper and coral trout grouper) and Viet Nam (snubnose pompano, lobster and cobia) conducted.

Output 3: Better management practice guidelines for marine cage culture focusing on key species in Indonesia, Thailand and Viet Nam developed and disseminated.

Output 4: Farmer trainings conducted, demonstration farms established and farm visits carried out to promote BMPs

3. Development of the marine finfish backyard hatchery industry in Viet Nam

Background

Marine finfish cage culture has significant potential in Viet Nam, and the country has a wide range of suitable environments for marine cage culture. The country is also near the major Chinese market for marine finfish, and due to the low transport costs, it can deliver live fish to the market. As a result, live fish from Viet Nam commands higher prices than other countries in the region - boats of buyers from Southern China travel down to Southeast Asia to collect the harvests.

Issues to be addressed

Though Viet Nam commands a high price for its live marine fish products, the sector is constrained by a lack of local fingerling hatcheries. This means that fingerlings are either wild caught, or imported at high cost. The imported fingerlings are often of a poor quality, and usually they could not have been sold to the local farmers in the country of origin. Furthermore, during transportation fingerlings are subject to high levels of stress, resulting in poor condition and quality.

Marine finfish hatcheries are all but absent in Viet Nam. The government hatchery in Nha Trang has state-of-the-art research and development facilities, but there is insufficient professional staff to make the effective use of the well-equipped facility. The government hatchery is primarily geared to research and development, but has the facilities (e.g. large broodstock holding/spawning tanks and associated egg collection equipment) and the specific expertise to produce large quantities of fertilized marine finfish eggs.

In comparison, Indonesian backyard shrimp hatchery producers, with training and technical advice from the Government breeding and hatchery experts, have successfully transformed into marine finfish seed producers. The backyard marine finfish producers generally do not hold broodstock - large tanks are required to hold broodstock and each broodstock pair can produce more eggs than a small-scale/backyard hatchery can use. As a result, fertilized eggs are purchased from the government hatcheries, or private facilities holding broodstock. In terms of Viet Nam becoming self sufficient in marine finfish seed production, the backyard hatchery model of converting ex-shrimp backyard hatcheries into marine finfish hatcheries shows significant promise.

Objectives

To develop a small-scale/backyard marine finfish hatchery industry in Viet Nam.

Target beneficiaries

The target beneficiaries are the marine finfish cage farmers, who are mostly small-scale producers. It is also anticipated that some of the backyard shrimp hatcheries that have been converted to marine finfish hatcheries will also benefit from the project.

Outputs

Output 1: A model of a marine finfish hatchery industry developed that illustrates linkages between:

1. Broodstock holding facilities producing fertilised eggs
2. Backyard hatcheries producing fingerlings
3. Growout cage farms producing table fish

Output 2: Small-scale shrimp hatchery operators interested in becoming marine finfish hatchery operators are identified.

3.5 SUMMARY REPORT OF MISSION ACTIVITIES

This section describes the activities and salient findings of the mission.

1) Indonesia

Key activities in Bandar Lampung included farmers' interviews, workshops with project partners, and a stakeholder workshop with farmers. Interviews with cage farmers were undertaken to determine current feeding activities, their knowledge of the trial results, the level of uptake of the trial results, and the identification of the current issues and constraints to their culture activities that could be solved with technical assistance from FAO and other development agencies. Interviews with hatchery operators were undertaken to evaluate the major constraints to the supply of fingerlings to the growout sector. Discussions with project partners were undertaken to clarify issues and gaps relating to the participatory trials that compared the use of trash fish/low-value fish with pellet feeds for brown-marbled grouper.

A stakeholders' workshop with farmers and staff from Main Centre for Mariculture Development (MCMD) was facilitated to provide information to non-trial farmers about the farmer participatory trial results, further understand the current practices, the level of uptake by the farmers of the project findings, the current issues and constraints to grouper culture development, and to prioritise potential project concepts to assist the development of the sector.

Findings

Growout farmers' interviews

Four growout farms were visited (two of the farms also operated hatcheries). The farmers who were visited have shifted to culturing humpback grouper as their primary culture species. This was due to their high market price when compared to brown-marbled grouper. As the trials were undertaken with brown-marbled grouper, the trial results were not directly applicable to humpback grouper. One of the two non-trial farmers who was visited knew about the trials and trial results. However, he did not implement the recommendations as he was raising humpback grouper. The other farmer visited was a relative of one of the farmers involved in the trial, but was not familiar with the trial results.

Hatchery farmers' interviews

The main hatchery area is Kalianda which is far from the growout farms, and is characterized by its exposure to unsheltered seas and the availability of good quality seawater. There are 18 small-scale 'backyard' marine finfish hatcheries in the Kalianda area, and three more hatcheries outside the Kalianda area but within Lampung Province (a total of 21 hatcheries are located in Lampung Province). The hatcheries are primarily producing humpback grouper fingerlings as this is the popular species in the Lampung area. The hatcheries purchase fertilized eggs from the government hatchery, or produce fertilized eggs from broodstock held in cages at the growout sites. One hatchery reported holding its own broodstock on site.

A typical hatchery runs 3-4 production cycles per year. One cycle comprises a batch of eggs that are reared to fingerling size (4 –8cm total lengths). Typically, each batch that is received by the hatchery comprises 30 000 to 40 000 eggs. However, there are also 2–3 larger hatcheries that can accommodate 300 000–500 000 eggs per month. Stocking densities are about 500 fingerlings per 4 m^3 tank. It takes between 3–4 months for the eggs to hatch and grow to a size that is ready for stocking into the growout cages (4–8 cm). The fingerlings of the humpback grouper are currently sold for about US$0.2/cm (= 1 800 IDR). Most of the grouper hatcheries were converted from old shrimp hatcheries where disease issues have resulted in reduced demands for shrimp PL. In this regard, many shrimp hatcheries have gone out of business and are remained unused.

Hatcheries operate on a flow-through basis. Water is treated as it enters the farm. Farms use mostly activated carbon (from coconut husks) and sand to filter incoming seawater that is pumped into the hatchery from a depth of about 10 m, and 100 m from the beach. Depending on the weather and the water quality conditions, the filter media are changed every 4–7 days - rainy conditions results in high water turbidity clogging filters, requiring their frequent cleaning. Hatcheries often use antiseptics such as iodine to treat incoming water, and maintain sanitary conditions to reduce disease problems.

In terms of hatchery feeding protocols, *Artemia* are enriched with different commercial enrichment liquid/oils that are designed for rearing of marine fish larvae. Pellets are also mixed with enrichment lipids (HUFAs), and a vitamin and mineral mix to improve their nutritional profile.

Hatcheries suffer from a range of diseases including parasites, viruses and bacteria. Disease prevention and treatment protocols are briefly as follows: eggs are bathed in antiseptic and freshwater on arrival at the hatchery. Separate equipment is used for the larvae and larger fish. Prophylactic treatments of freshwater with an antiseptic are provided. If a disease occurs, the water in the tank is replenished, and therapeutic treatments are applied. Though survival to marketable size (4–8 cm) is only 3 percent, the hatchery operation remains highly profitable.

Farmers' workshop

Sixteen growout farmers attended the workshop. Some of the farmers also operated hatcheries. Generally, the farmers cultured humpback grouper, and sometimes brown-marbled grouper or other fish species. Farmers attending the workshop had between 3 months to 20 years experience (mean: seven years of experience). In terms of feed use, they reported that between 5 to 25 percent of their feed was pellets (generally about 20 percent), with the remainder being trash fish/low-value fish.

Generally, fish are fed pellets when they are small (<10 cm or less than 250 g), the larger fish are fed trash fish/low-value fish. The farmers' reasons for applying these feeding practices were that the trash fish is time consuming to cut into small pieces for the smaller fish, and the pellets for smaller fish give a reasonable growth rate in comparison to trash fish/low-value fish. Furthermore, when humpback grouper are fed the larger pellets (>5 mm) that are suitable for larger fish, the growth rate is inferior to that achieved when feeding trash fish/low-value fish.

There are imported brands of formulated marine fish feeds that farmers reported could be used to produce growth comparable to that of trash fish/low-value fish. The brands reported by the farmers included: NRD (Thai brand) and Otohimi (Japanese brand). However, the price for these feeds is about three times higher than the price of trash fish/low-value fish. The current price for Commfeed (Indonesian brand) is about US$ 1.5/kg (376 000 IDR/25kg bag).

2) Viet Nam

The key activities were based around Nha Trang, Viet Nam, and included farmer interviews, discussion with project partners, and a stakeholder workshop with farmers. Interviews with cage farmers were undertaken to determine current feed practices, and establish their knowledge of the trial results, the uptake of the trial results, and identify current issues and constraints to their culture practices that could be solved with technical assistance from FAO and other development agencies. Interviews with government hatchery and others about the status of the marine finfish hatchery industry, and sources of fingerling were undertaken to evaluate any major constraints to fingerling supply to the growout sector. A stakeholders' workshop was held with the farmers and staff from Research Institute for Aquaculture No. 3.

Findings

Growout farmers' interviews

Farmers are primarily growing lobster and cobia. Cobia production from the Nha Trang area in Viet Nam is about 400 tonnes/year. Other species cultured include red snapper, snubnose pompano, coral trout grouper, orange-spotted grouper and brown-marbled grouper and pink ear emperor (*Lethrinus lentjan* - a new species introduced for cage culture, locally known as 'gay gay' in Vietnamese). Some farmers have begun to try pellet feeds. Farmers have a little knowledge of pellet quality, and some farmers were using a freshwater catfish feed. However, as the fish did not grow well on this formulation, one farmer has switched to "Tomboy", a brand of marine fish pellets, and is now observing improved growth rates. Farmers are feeding to satiation, with some farmers using the initial stocking weight of the cage to guide the initial feeding level. Even those farmers that use pellet feeds also use trash fish/low-value fish for their lobster and the larger cobia - pellets suitable for these species/sizes are not available in the market. Larger cobia (older than three months or 0.5 kg) require a very large pellet, and larger than those currently available in the market. In contrast, to suit its slow feeding habit, lobster requires a pellet that is water stable.

Prior to feeding, some farmers soak their pellets in water to soften them. This they believe increases its palatability. This practice may result in a large loss of nutrients from the pellets, and will likely result in reduced growth rates. It was evident that the farmers have a low level of understanding of appropriate feed management practices (either trash fish/low-value fish or pellet feeds), or of marine cage farming in general.

Disease is sometimes an issue for the farmers. Farmers use freshwater baths on a regular basis to reduce parasitic infestations. Freshwater baths are typically given every 10 to 15 days. Antibiotics are also used in lobster culture. Some farmers only administer antibiotics (human grade medicines obtained from pharmacies) when the lobsters appear sick, however, other farmers administer antibiotics as a prophylactic, and on a regular basis (such as three times per month). It is likely that the inappropriate use of antibiotics will lead to antibiotic resistant strains of bacteria in lobster culture systems. Guidelines on disease treatment, including the use of registered products and withholding periods would assist the sustainability of the lobster culture industry.

Local fingerling supplies are sourced from the government hatchery and one private hatchery. Currently, supply volumes cannot be met by local production. Fingerlings are therefore also imported from Taiwan POC, and these are often of low quality. The reliance on imported fingerlings is a major problem for the expansion of the local industry. When available, farmers are also using wild caught fingerlings, for example, pink ear emperor fingerlings. Some farmers reported waiting for Nha Trang University to import pompano fingerlings for sale to farmers. The lack and irregularity of fingerling supply is one of the major constraints to the expansion and profitability of the industry.

Hatchery farmers' interview

The government hatchery has excellent facilities and equipment but is short of experienced professional staff. Undertaking of large-scale spawning and the nursing activities to meet the commercial demand may take staff time away from their research and development activities, which are the primary aims of the centre. Production is a commercial responsibility, and in this respect a local hatchery industry should be encouraged and supported. The Indonesian model of backyard hatcheries that buy fertilized eggs from the government centres (that have large broodstock holding tanks), and culture the juveniles until they reach fingerling size, could be adopted in Viet Nam.

Farmers' workshop

Twelve grow-out farmers attended the workshop. In general, the farmers cultured lobsters (several species are cultured) and/or cobia. However, some farmers reported culturing grouper, pompano, red snapper and the pink ear emperor.

Farmers requested the development of marine cage culture guidelines, and training assistance to improve their culture practices in marine cages.

The marine cage culture industry in Viet Nam is constrained by a lack of fingerlings. Most fingerlings are imported from Taiwan, and there are issues of poor seed quality, delays in receiving fingerlings when they are required, and variable fingerling sizes in the same shipment. The farmers prioritized local hatchery production as a way to resolve these issues.

The farmers expressed concerns about the sustainability of lobster culture. Currently, this is the primary culture species in the area. Small lobster for on-growing in cages are caught in the local area where there is an abundant resource. The lobsters are primarily fed on trash fish/low-value fish but also on bivalves. Farmers would like to use pellet feeds but currently the pellets that are available are unsuitable due to their low water stability. Lobsters are slow feeders, and therefore prior to ingestion, the pellets must be water stable for at least 45 minutes.

3) Thailand

The activities that were undertaken in Krabi, Phang Nha and Phuket included farmer interviews, workshops with project partners, and a stakeholder workshop with farmers. Cage farmers were interviewed to determine current feed management practices, and establish their knowledge of the trial results, the uptake of the trial results, and the current issues and constraints to their culture practices that could be solved with technical assistance from FAO and other development agencies. Interviews with government hatchery personnel (the primary supplier of fingerlings for small-scale farmers) and other stakeholders in the marine finfish hatchery industry were undertaken to evaluate the major constraints in the supply chain.

A stakeholders' workshop was organized with 18 farmers (seven women) from the three areas (Krabi, Phang Nga and Phuket), and the staff from the Krabi and Phuket Coastal Fisheries Research Centres. The workshop was designed to provide information to non-trial farmers about the farmer participatory trial results, gain further understanding of the farmers' current culture practices and their adoption of the project findings, identify current issues and constraints to marine cage culture development, and to prioritise potential project concepts to assist marine cage culture development.

Findings

Growout farmers' interviews

Marine cage farmers in the Southwest region of Thailand (which includes Krabi, Phuket and Phang Nha) culture fish primarily for the domestic market. This area of Thailand is a popular tourist destination, and the live marine fish are primarily targeted to high-end restaurants catering to tourists. Though the export markets such as China, Hong Kong SAR of China, Taiwan POC and Singapore pay high prices, the transport costs to these markets from the west coast of Thailand is high - either as air freight or by boats that travel down the west coast of Thailand and Malaysia to reach Singapore and then sail back to China. The high transport costs and the relatively high demand and prices obtained on the local market, make the local market attractive to marine fish farmers.

Depending on the environmental conditions (primarily salinity), a number of species are cultured. These include barramundi or Asian seabass, brown-marbled grouper, orange-spotted grouper, cobia, pomfret, giant grouper, red snapper and coral trout grouper.

Conflicts with other resource users such as vessels (navigation), and infrastructure development is an issue in the region. For example, a marina is being built adjacent to sites of some of the project trial farmers. These farmers have since moved further upstream from the marina. There is also potential conflict between aquaculture zones and fishing zones, and more conflicts of this nature are expected in the future.

Generally farmers use low-value fish/trash fish but many of them also use pellet feeds (usually in combination with trash fish). A problem that was reported was that the pellet feeds can be difficult to obtain, and the ones that are available are not always suitable for marine finfish, or are out of stock. In addition, farmers' cash flow is often inadequate, and they cannot always afford to purchase the pellet feeds. The 2004 tsunami and the floods that have recently affected the area have also had a severe impact on the industry in terms of infrastructure damage, the loss of stock, or both.

Farmers' workshop

The workshop discussion focused on six related issues. The farmers were divided into three working groups by province (Krabi, Phang Nga and Phuket), and addressed these six questions: (i) why they do not use more pellet feeds; (ii) why their yield is low or not higher; (iii) why their costs are high or not lower; (iv) why their profit is low or not any higher; (v) why they cannot expand their farm; and (vi) what are the major risks at their farm? A women's mini-workshop was also convened to describe their roles and constraints to fulfilling some of these roles.

The responses, compiled from the three groups, are as follows:

1. **Why they do not use more pellet feeds**. The constraints ranged from the high cost of feed to absence of a local dealer. The two commonly cited constraints were high cost of feed and lack of capital. A group that cultivates mostly grouper cited the lack of species- specific feed formulation. A few thought the fish grew slowly on pellet. In relation to feed cost, they put the acceptable price of feed at the time at US$ 1.30-1.40/kg. They also suggested a packaging size of 5-10 kg a pack rather than the current 20 kg pack. The volunteered to provide the feed company with feed size mould for different stages in the fish growth (i.e., starter, grower, finisher).
2. **Why yields are low or not any higher**. The constraints were a combination of economic constraint and natural hazards: uncertainties in the business so that they are reluctant to intensify and lack of capital so that they cannot even if they wanted to for the former, and disease, the shortage of fingerlings and natural hazards such as flooding for the latter.
3. **Why production costs are high.** As might be expected, the high cost of feed (both pellets and low-value fish) is the prominent constraint. The farmers cited a number of reasons, which include the high cost of transport - as the source of pellet feed is far, the higher cost of fishing from an increasing fuel cost as some of them fish for their own low-value fish, and the need to buy low-value fish from a distant place during closed fishing season.
4. **Why profits are low or not any higher.** Not surprisingly, their reasons are a combination of the high cost of inputs and low product price i.e. increasing feed costs, high cost of seed and low buying price set by middlemen. The other two reasons are a low level production - which is a result of lack of seed, and lack of capital to expand and low yields as a result of, mostly, fish mortalities. One bright note came from one group of farmers who are members of a cluster. They claimed that since they started the business they have not lost money and that their profitability is usually around 45 percent over operating cost.
5. **Why they cannot expand the farm.** A variety of constraints prevent them from expanding, an obvious pair being a limited culture area and lack of capital, but also insufficient labour - the high cost of labour is also felt because the three

provinces are major tourist areas and workers tend to look for jobs in the service sector. Some said they might expand if feed costs were lower. Some farmers said the low water salinity in the growing site does not allow growing some preferred species such as coral trout grouper.

6. **Major risks.** Uncertainties in the business and various natural hazards comprise the risks that they perceive to be significant including the natural disasters, diseases, and the abundance of predators especially monitor lizards in culture areas near mangrove.

During an extended break in the workshop, the women agreed to organize into two working groups to discuss and provide answers to these issues: (i) the three most important problems related to the farm operations; (ii) three major problems in the household; and (iii) their role in the fish farming business.

On the first issue, the said they cannot operate the boat or dive to maintain the cages and some chores require intensive and hard work. Three major problems in the household include the predictable financial difficulty - more expenses than revenue and not having enough money to cover daily expenses. The two others are taking care of the children and spending more time with the family. Their major roles in fish the fish farming business include feeding as well as preparing the feed, marketing, net mending and some cage maintenance and preparing food for the workers.

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This technical paper presents the findings of an FAO Regional Technical Cooperation Project on the use of trash fish/low-value fish and pellets as feed for marine cage farming. Implemented in China, Indonesia, Thailand and Viet Nam, its components included a farmers' participatory on-farm trials and a concurrent survey of farmers' perceptions concerning the use of trash fish/low-value fish and pellet feeds and microcredit, environmental impact assessments of the use of two feed types, and a survey of the potential impacts of a change to pellet feeds on livelihoods of fishers and suppliers of trash fish. There were indications of benefits to farmers and the environment of adopting pellet feeds. Improving feed management can boost technical and economic performance from pellet feeds. The recommendations include providing the opportunities and enabling farmers to translate their positive attitude into sustained adoption of pellet feeds. Enablers include reasonable credit facility, species- and growth-stage-specific feed, farmers being associated and sound technical advice. Farmers requested a standardized better management practice guide in cage mariculture. Losing the cage culture industry as their direct market would have minimal impact on the livelihood of fishers and fish suppliers; they have robust coping mechanisms that policy and technical assistance from government could strengthen.

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