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

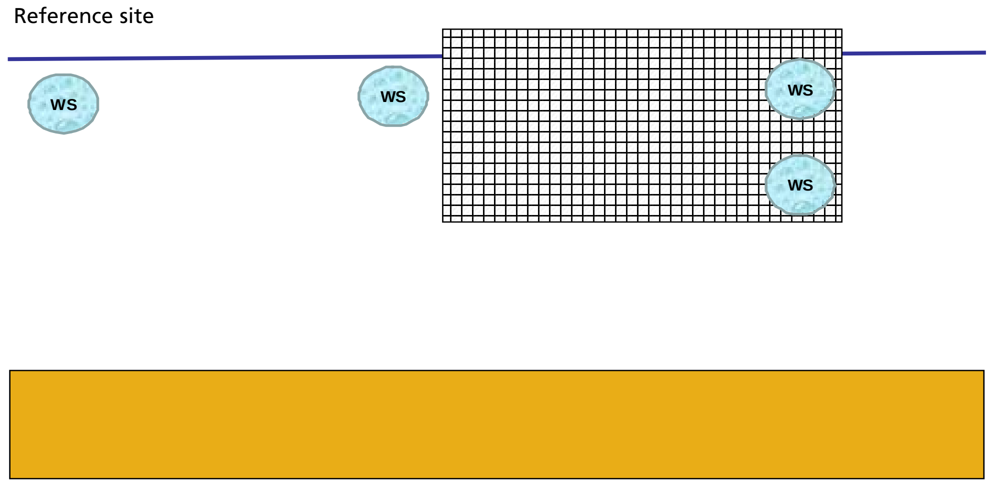
Routine water quality parameters were monitored at each of the farm sites, however the parameters that were monitored varied between the trial countries. The details of the water quality monitoring protocols that were adopted in the trial countries, and the results thereof, are provided in Annexure 1.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

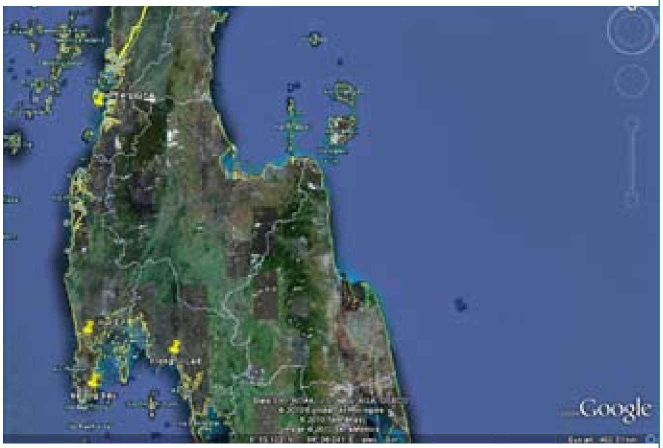
Under cage culture conditions, water exchange is one of the most important factors influencing environmental impacts and production carrying capacities. In order to assess water exchange and mixing at the cage sites, current speed, direction and dispersion were measured.

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:

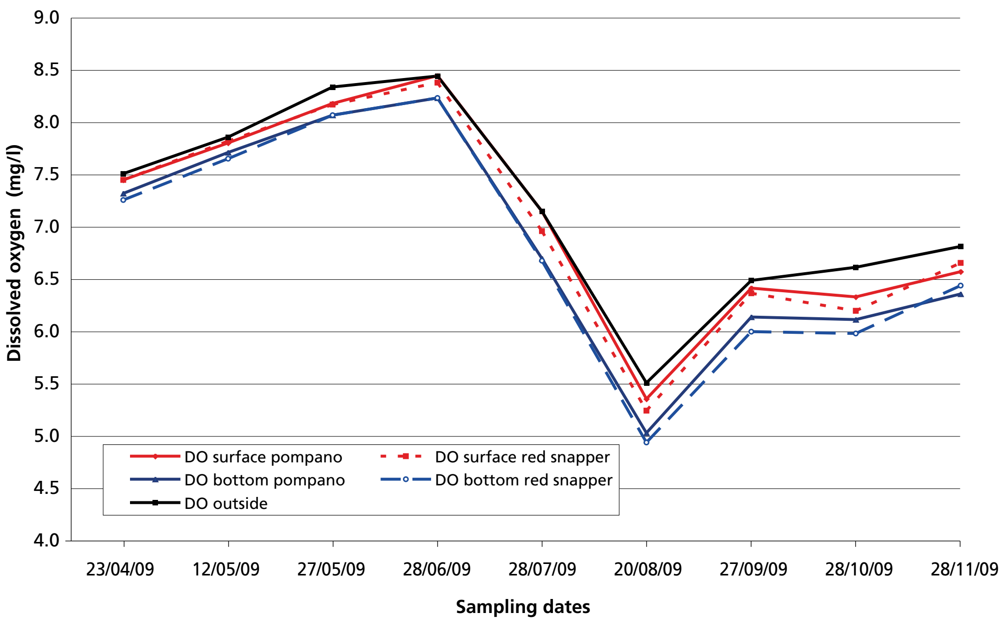
- Inside and outside of the cages
- Between the top and bottom of the cages
- Between cages that were fed pelleted feeds or trash fish
- Cages that were used to culture different species

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

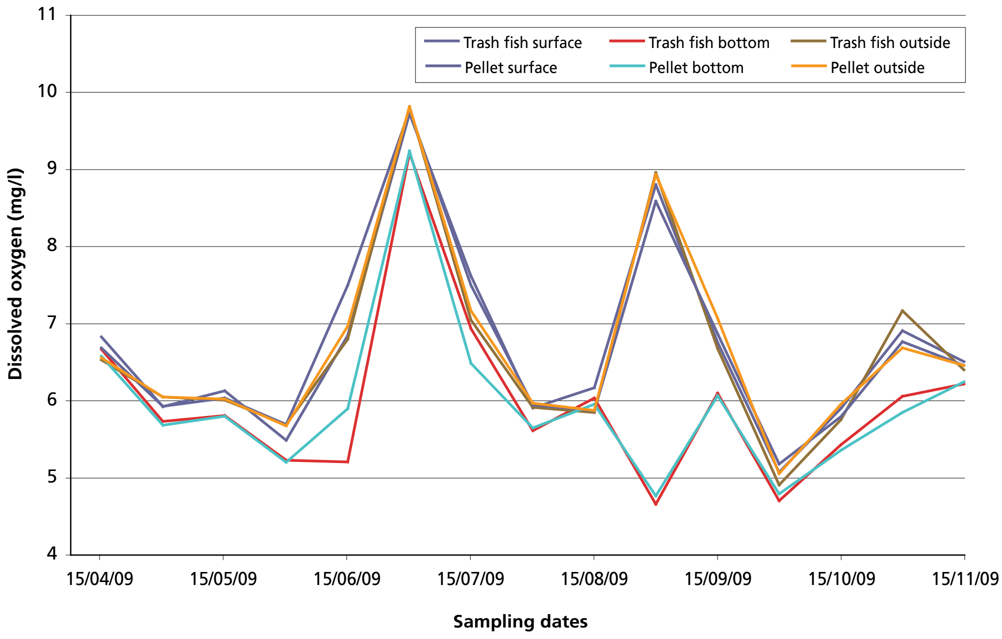


In China, the dissolved oxygen concentrations did not differ significantly between the samples collected from the surface, bottom or the surface waters outside of the cages, or between the samples collected in the cages culturing green grouper or red snapper. However, dissolved oxygen levels differed 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).

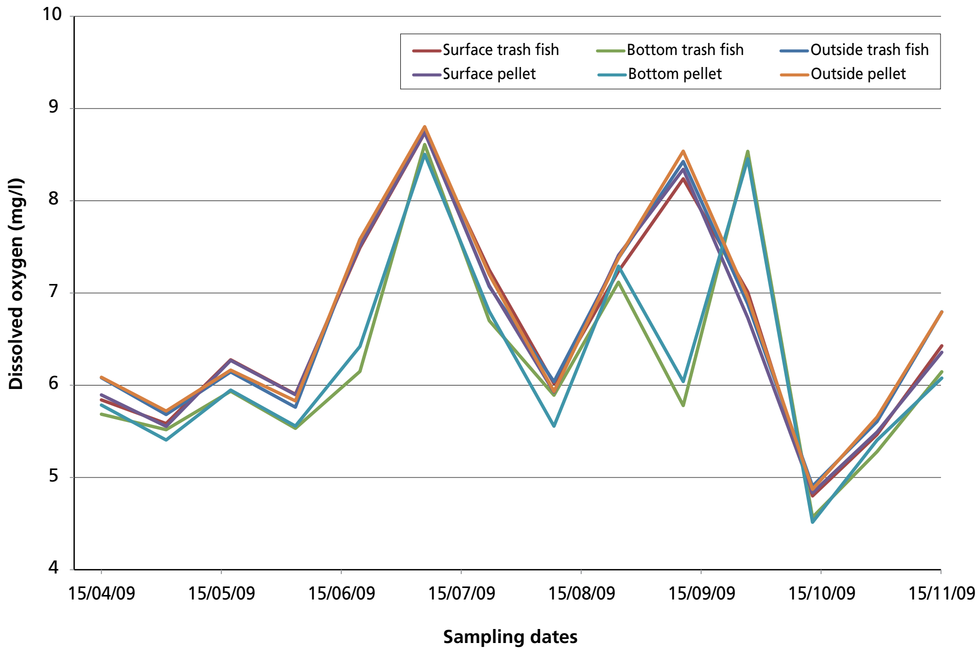
In Indonesia, dissolved oxygen levels were only measured at the farm level as shown by the farmer's name (e.g., Bobby, Parmato, Robby, Alung, Atiek and Sitepu). While there were significant variations in the dissolved oxygen levels between different farms, the differences were attributed to the farms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

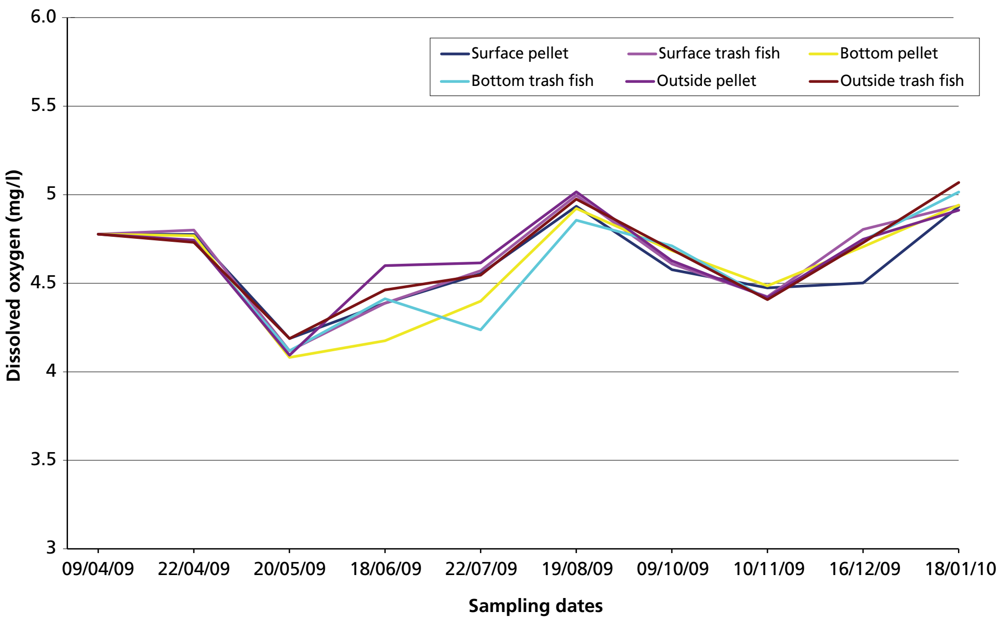
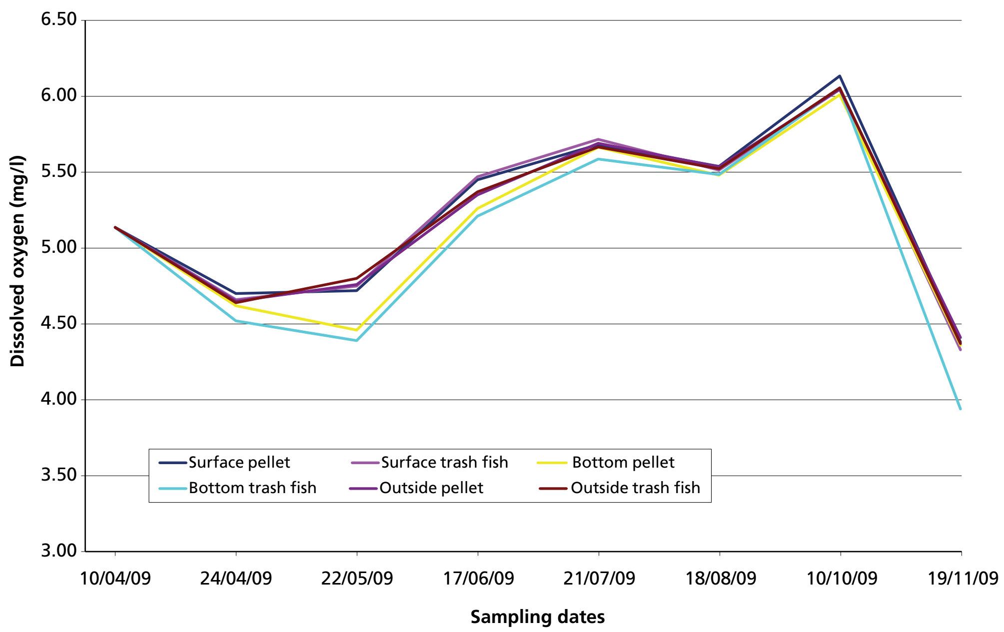


FIGURE 8
Dissolved oxygen levels inside (surface and bottom) and outside (surface) the barramundi cages in Thailand



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

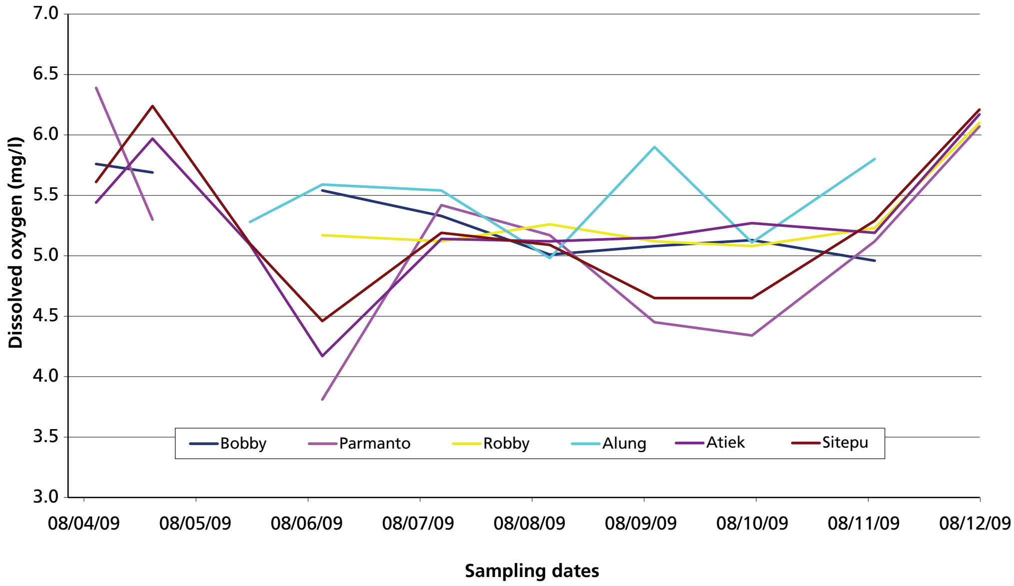
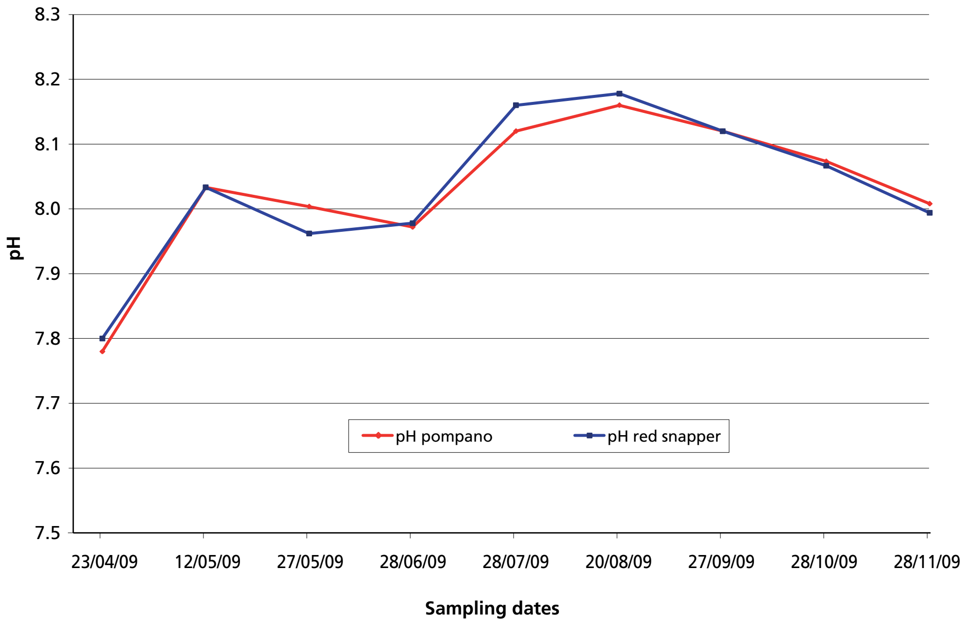


FIGURE 10
pH levels inside the snubnose pompano and red snapper cages in Viet Nam fed trash fish and pellet



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

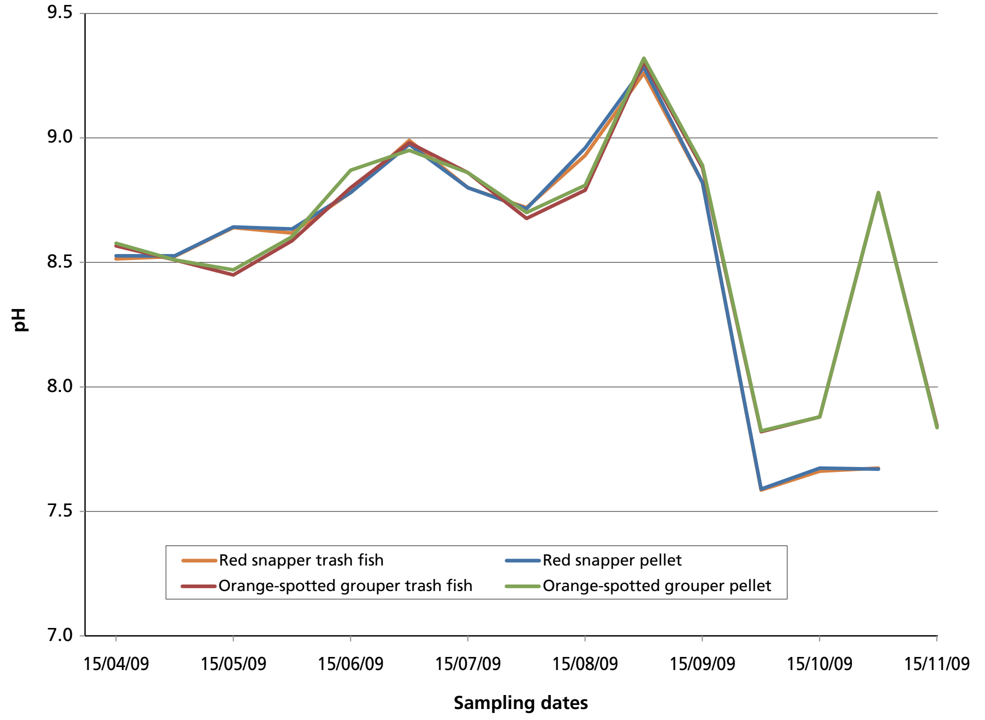
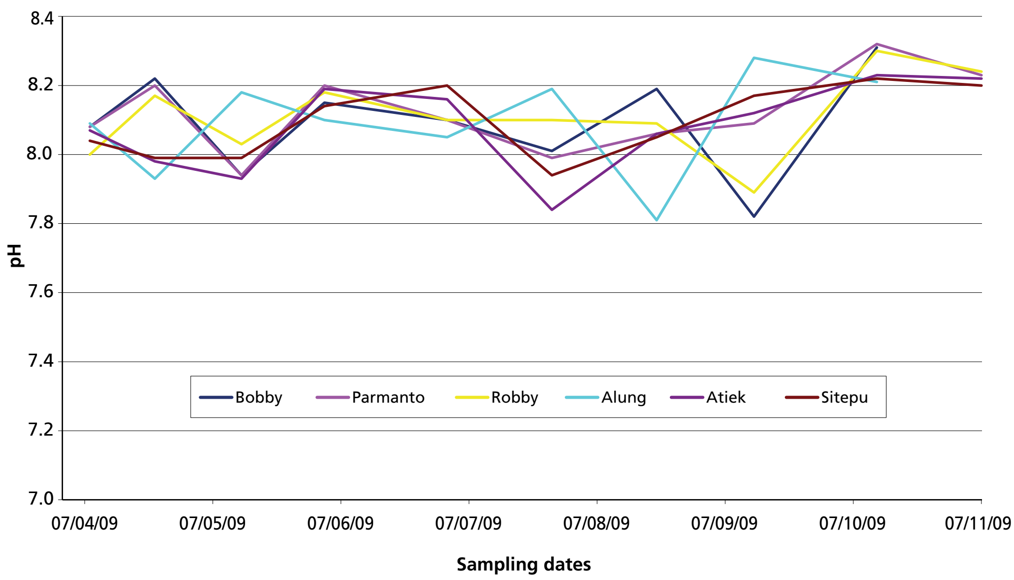


FIGURE 12
pH levels at different farms in Indonesia



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

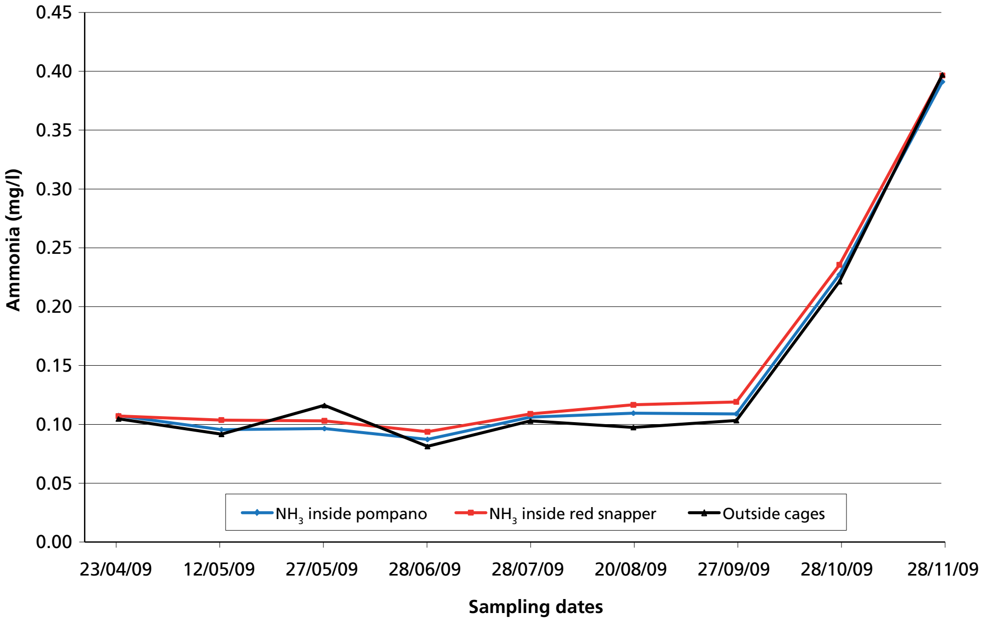


FIGURE 14
Ammonia levels inside (surface and bottom) and outside the barramundi cages in Thailand

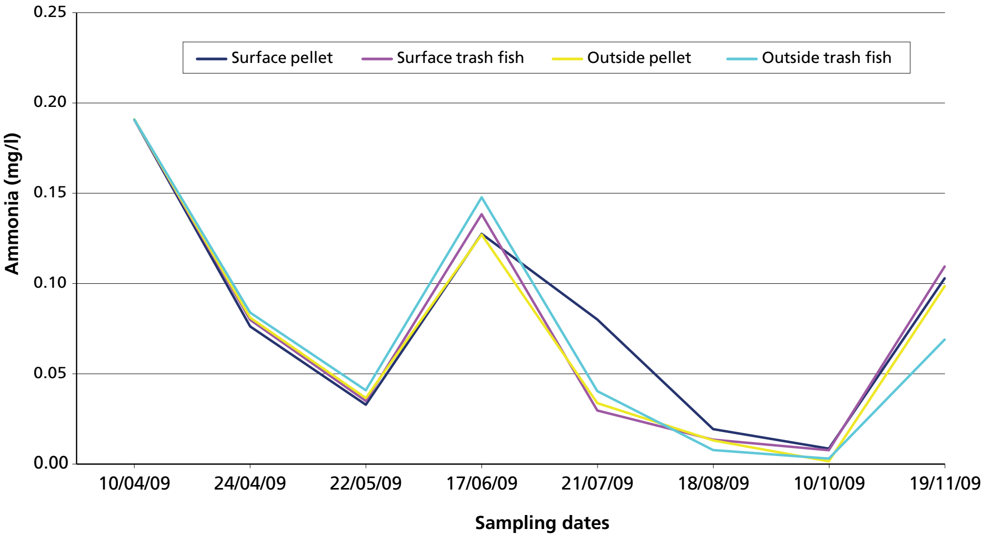


TABLE 4
The maximum recommended water quality levels in Indonesia

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

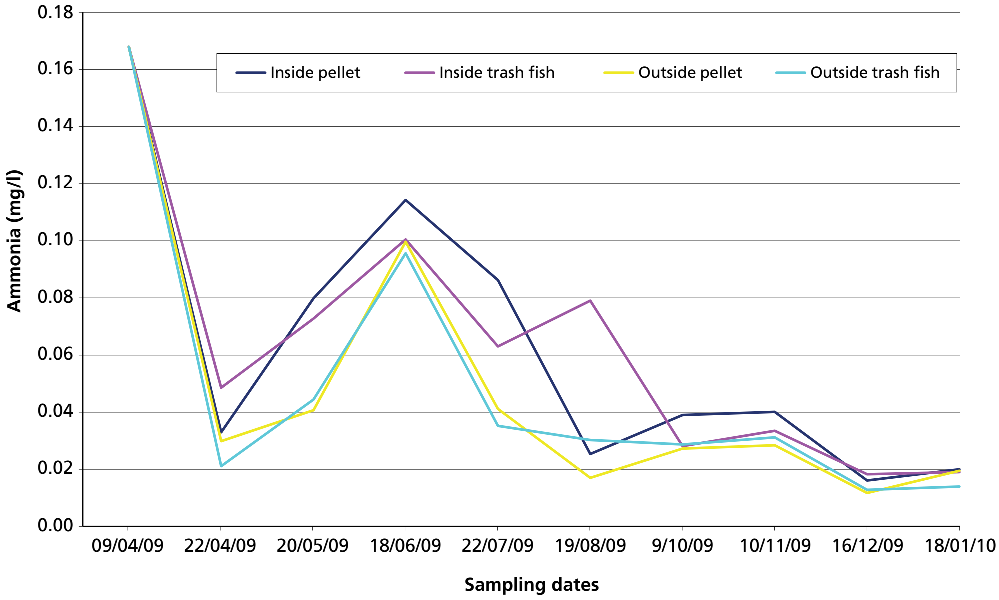
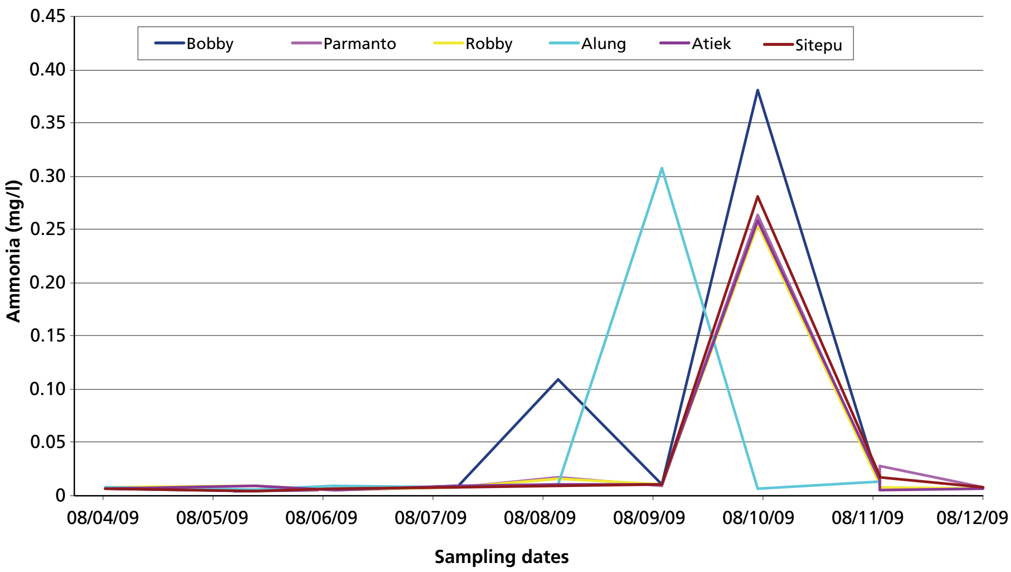


FIGURE 16

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

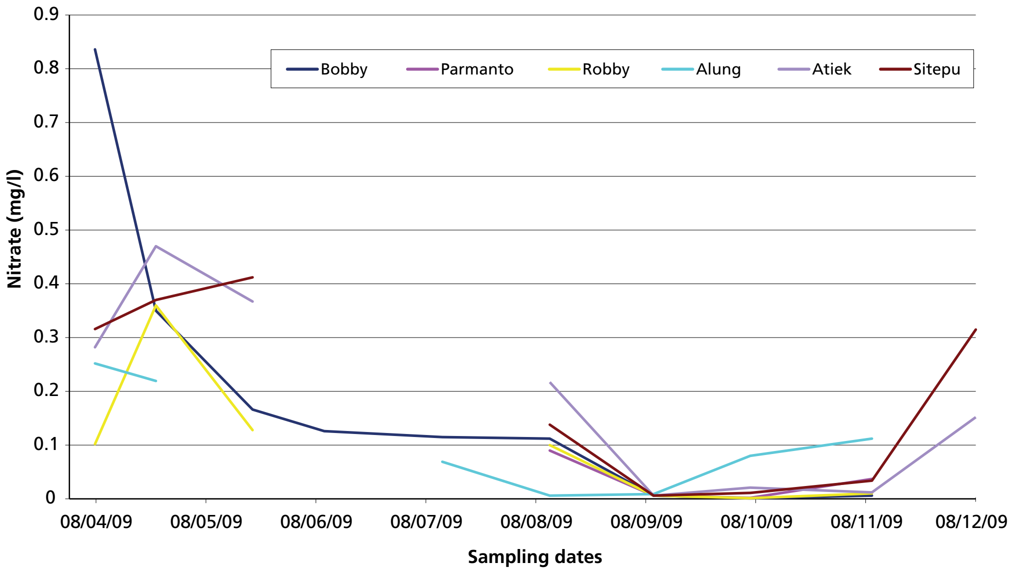
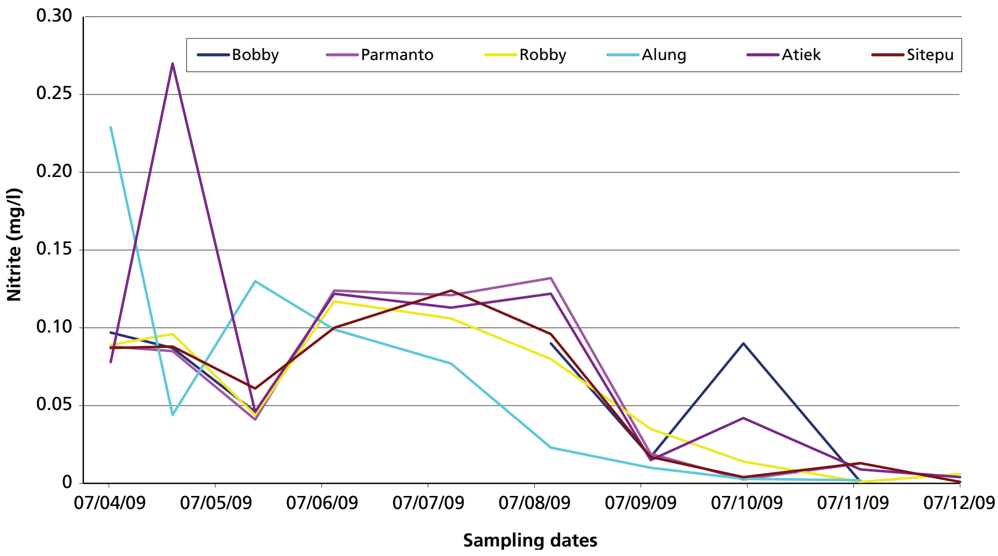


FIGURE 18
Nitrite levels at different farms in Indonesia

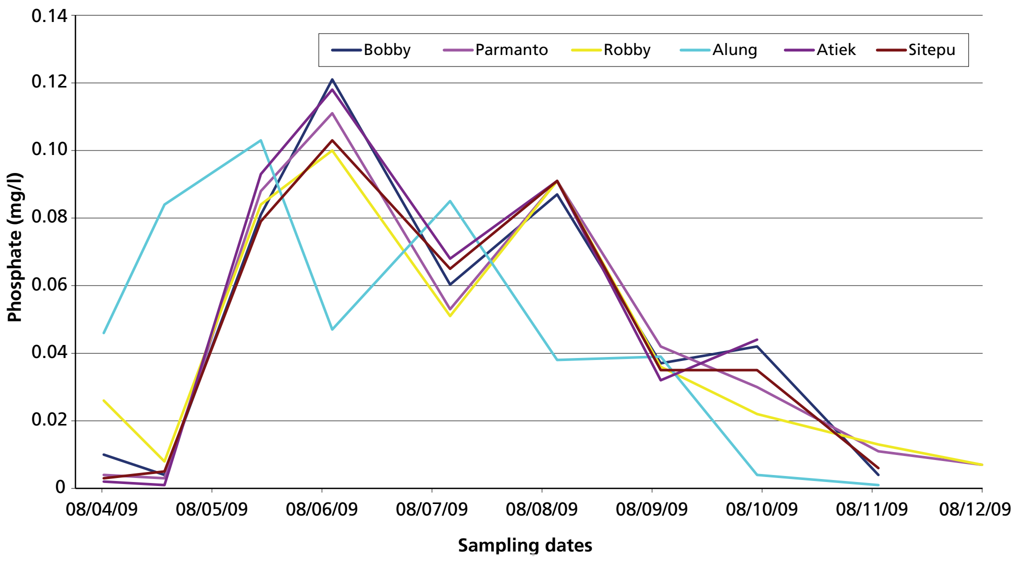


- **Thailand** - None of the water quality parameters differed significantly with feed types or species.
- **China** - None of the water quality parameters differed significantly with feed types.
- **Indonesia** - None of the water quality parameters differed significantly with feed types, the exception 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:

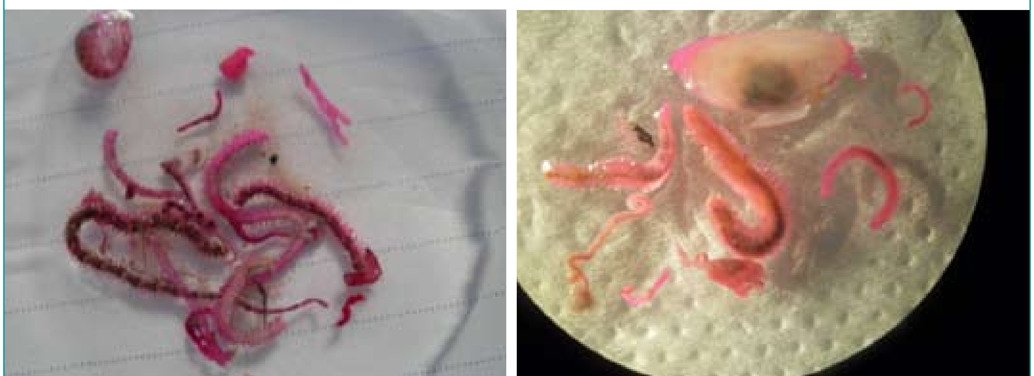
- Sediment type - shell hash, gravel, sand, or mud (silt and/or clay);
- Surface colour and colour change with depth - as a possible indicator of anoxia;
- Smell - sulphide (H_2S or a rotten egg smell), oily (petroleum tar), or humic (a musty, organic odour). Typically, un-impacted sediments have no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

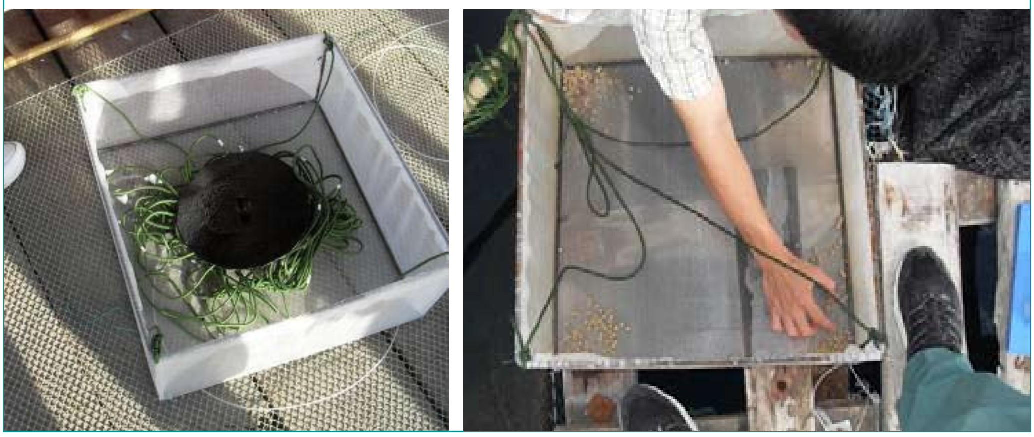
However at commercial production levels, 3m x 3m x 3m cages fed pellet feeds would typically have a holding biomass of 10 to 15 kg/m^3. This would give a stocking density of 30 to 45 kg/m^2 (cage surface area). At these densities, the environmental impacts between the farming activities are likely to 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



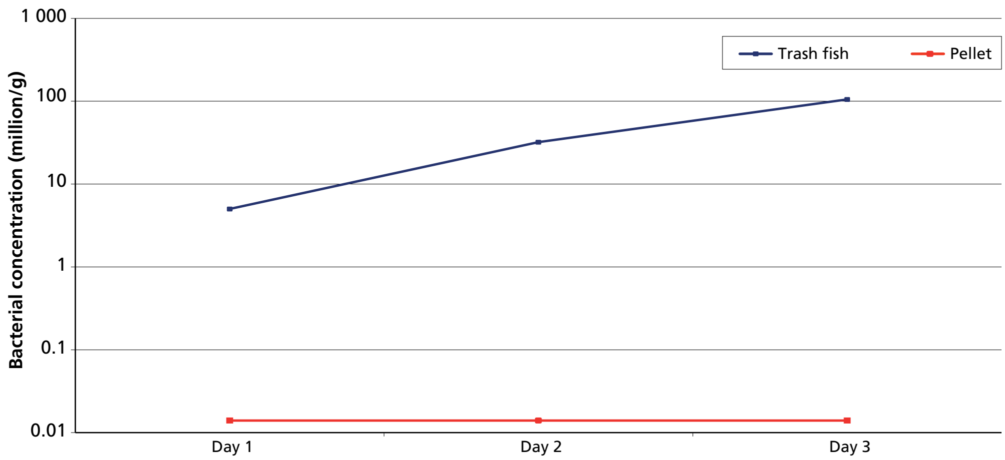
The results of the individual trials indicated an average of 228 uneaten pellets (20.45 g) in the feeding trays (0.25 m^2). Taking into consideration the distribution of uneaten pellets at the bottom of the cages, it was estimated that the farmer had been overfeeding the cages by 11.2 percent. It was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

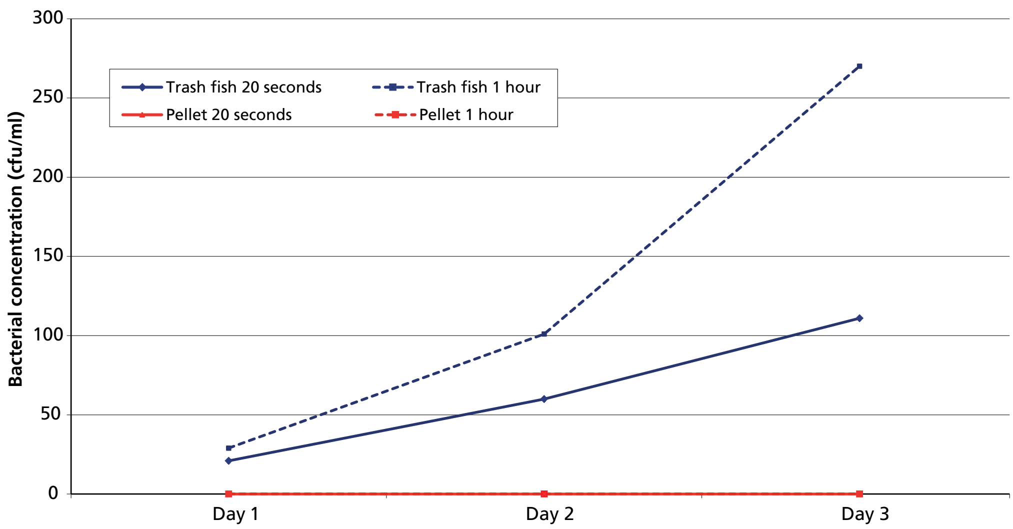
The results were analysed using an F-test to make comparisons of the components of the total deviation. Statistical significance was tested for by comparing the F test statistic where

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.

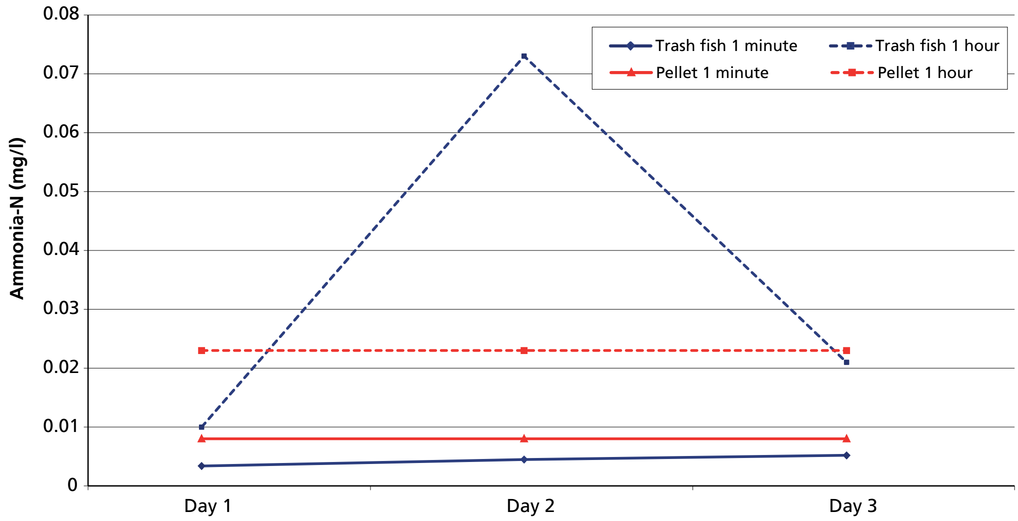
A trial was undertaken by MCMD (Lampung, Indonesia) to measure feed derived nutrient leaching to the water column during feeding. The leaching properties of three different qualities of trash fish (1 day, 2 day, and 3 day old fish) and pelleted feeds were established. The level of leaching was measured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

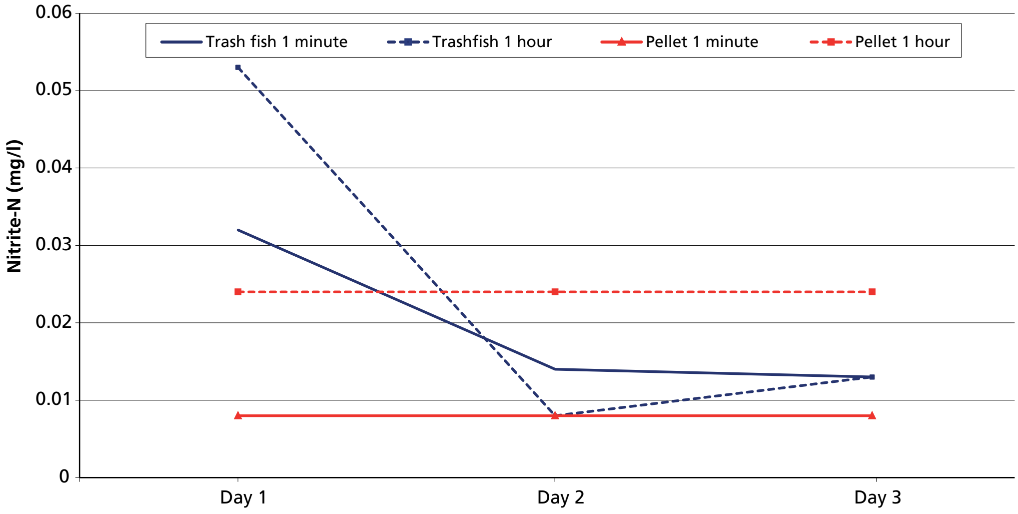


FIGURE 27

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

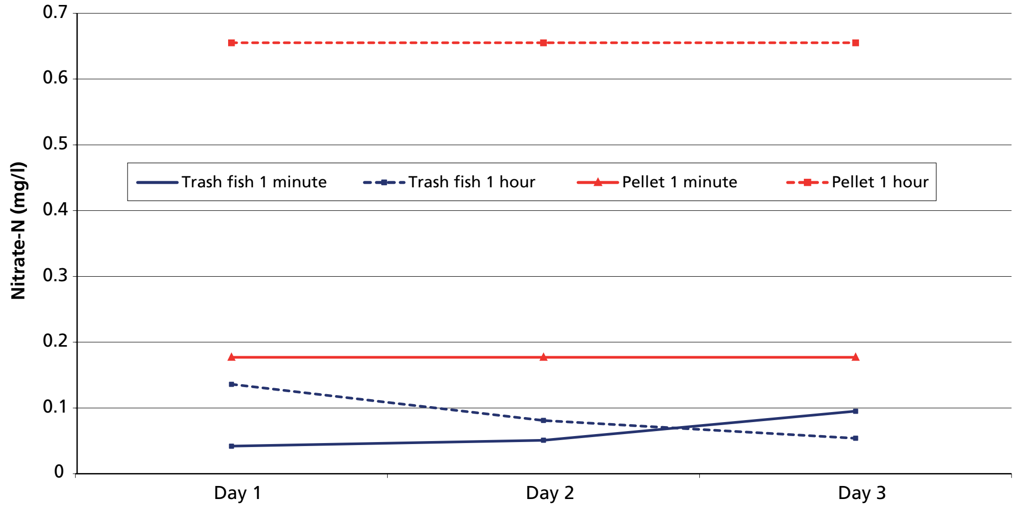
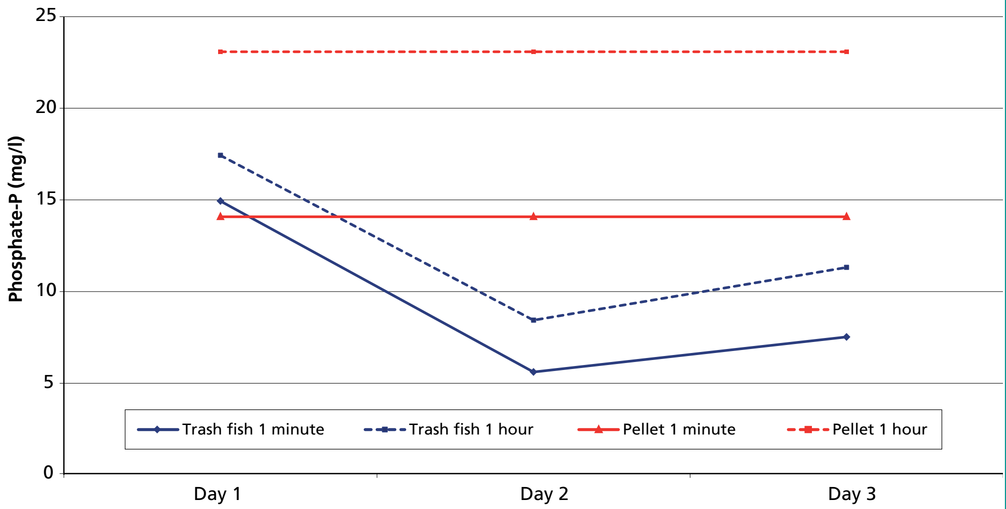


FIGURE 28

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

	Country				
Supplier type	**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

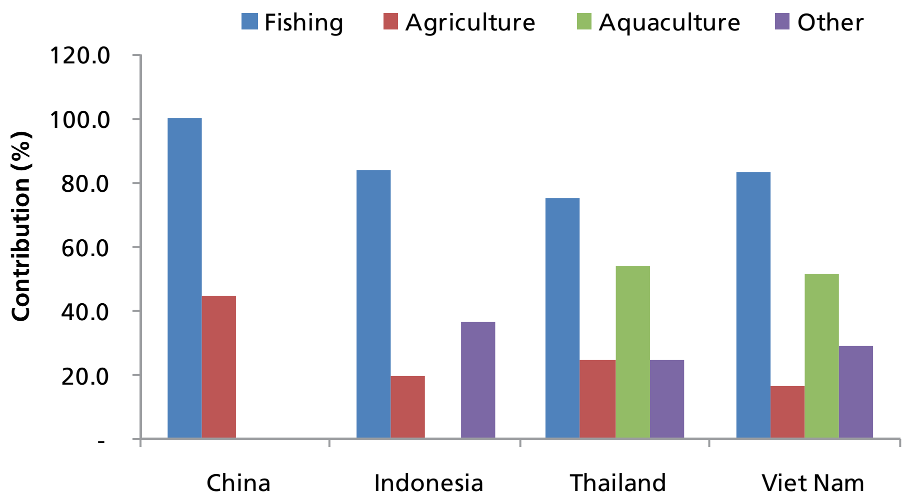


TABLE 2
Fishing as the primary income generating activity for the households surveyed

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).

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).

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**

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.

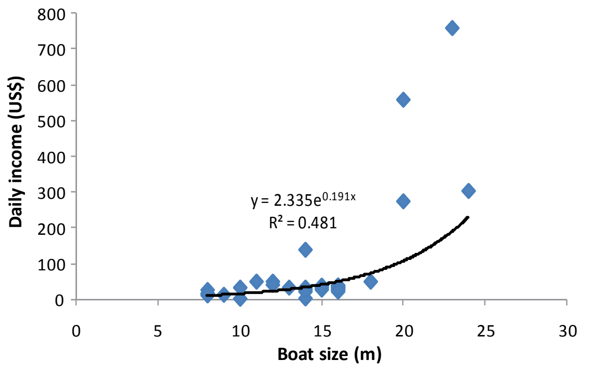
Of the 91 respondents, 71 indicated that there was seasonal variability in their fish catches. In China, August–October was seen as the best fishing period. In Indonesia, the full-moon period and bad weather were identified as factors that resulted in poor fishing. Fishers in Thailand were aware of seasonal 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



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 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.

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.

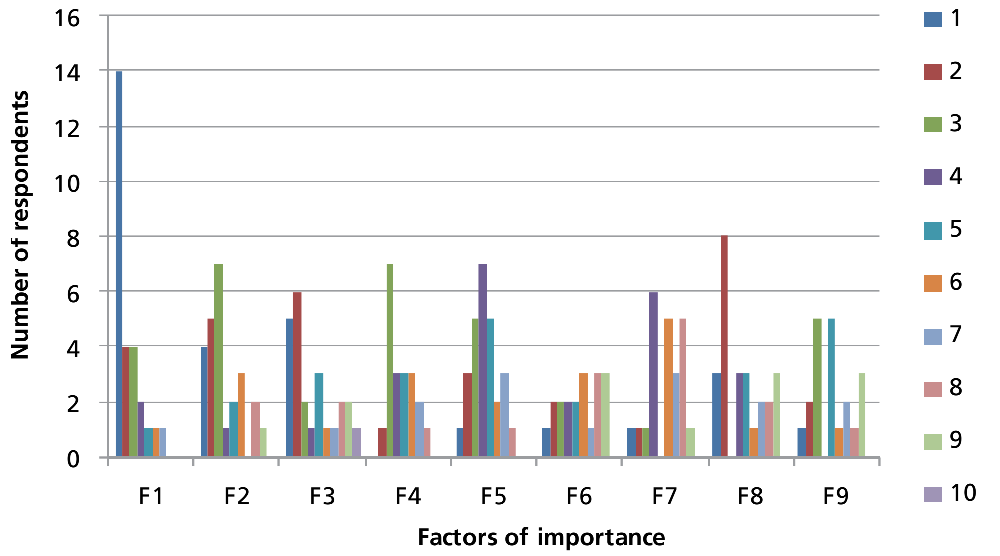
Notwithstanding the first three factors, *viz*., 1) easy access to fisheries resources, (2) good market for the trash fish/low-value fish (high and stable demand), and (3) the ease of undertaking the activity; the fishers considered the remaining factors to be less important. On the other hand, if one 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;

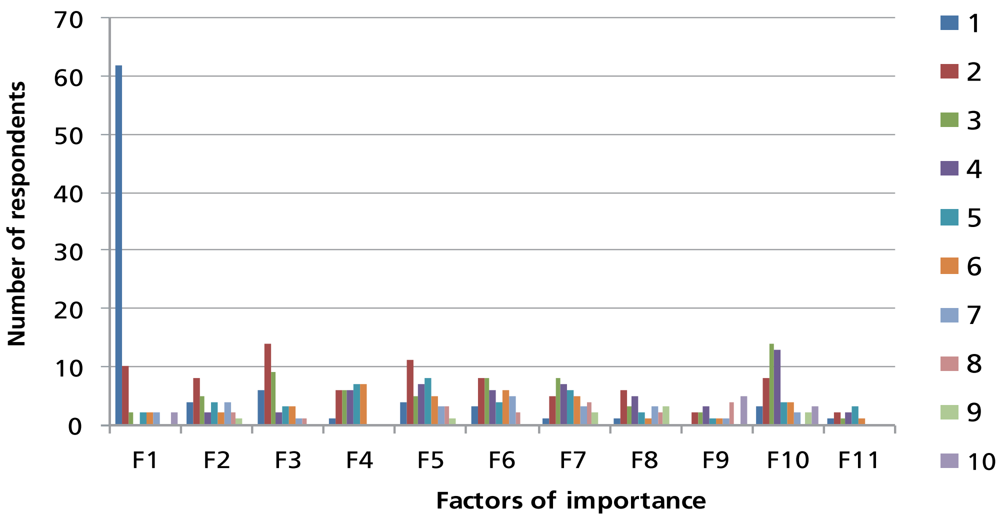
FIGURE 3
Fishers' ranking (1 to 10) of the factors that influenced whether a household engaged in fishing



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



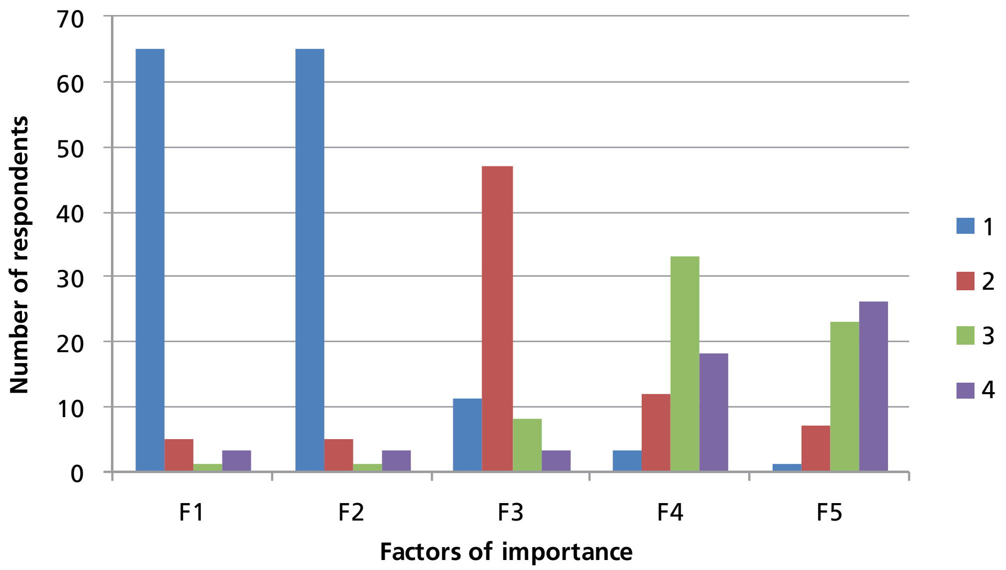
(iii) How fisher households would prepare for the future

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.