Part B – Annexes

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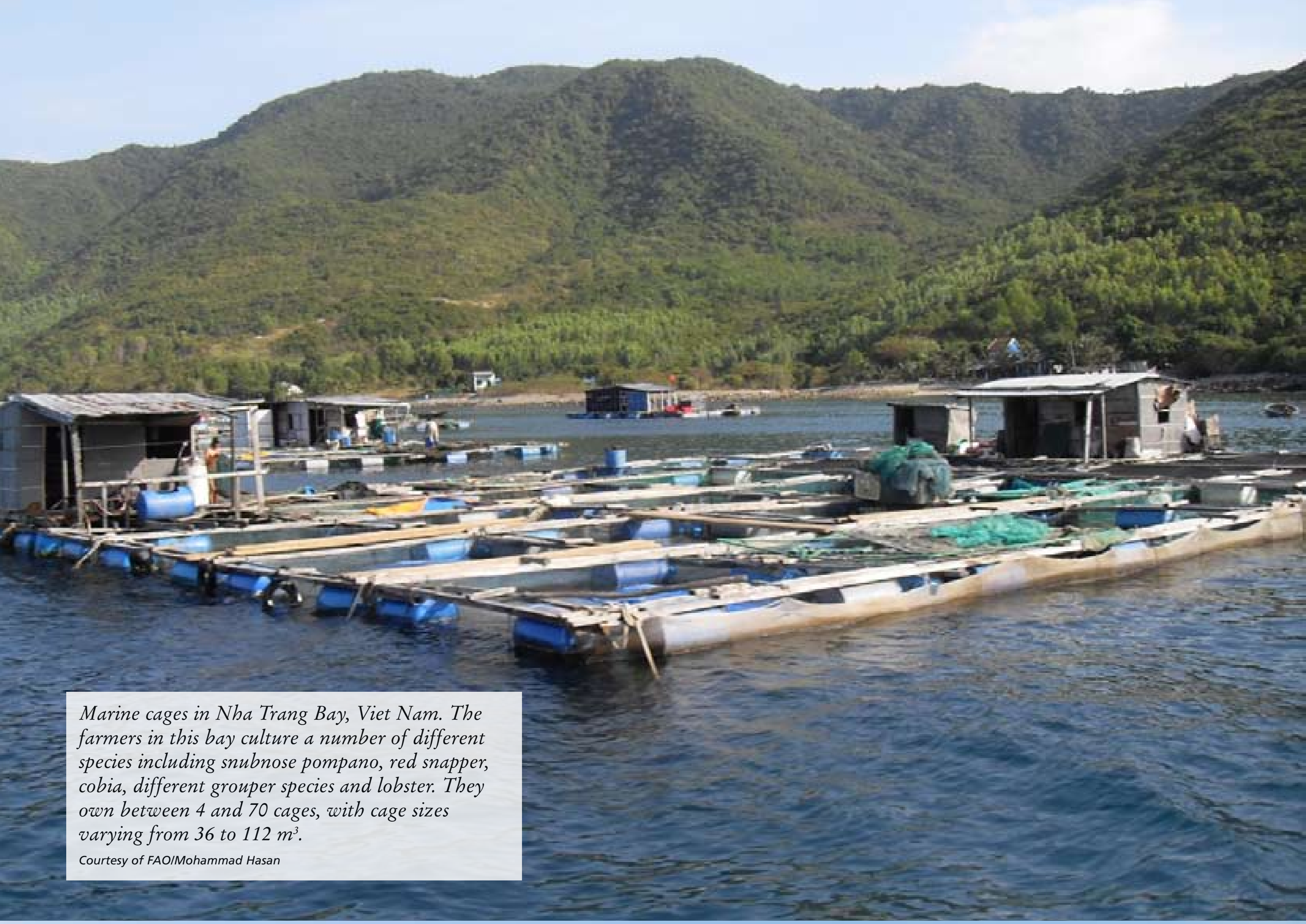


Marine cages in Nha Trang Bay, Viet Nam. The farmers in this bay culture a number of different species including snubnose pompano, red snapper, cobia, different grouper species and lobster. They own between 4 and 70 cages, with cage sizes varying from 36 to 112 m^3.

Courtesy of FAO/Mohammad Hasan

Small-scale marine finfish cages in Krabi estuary, Khlong Prasong district, Thailand. Cage sizes in this area are generally small varying between 10 and 18 m^3.

Courtesy of FAO/Mohammad Hasan

ANNEX 1

Farmers' participatory trials[1]

EXECUTIVE SUMMARY

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

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

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

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

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

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

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

1. INTRODUCTION

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

1.1 Objective

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

2. GENERAL METHODOLOGY

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

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

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

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

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

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

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

2.1 Proximate and amino acid composition

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

2.2 Performance parameters

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

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

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

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

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

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

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

2.3 Statistical analysis

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

3. FARMERS' PARTICIPATORY TRIAL: CHINA

3.1 Materials and methods

3.1.1 Farmers

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

3.1.2 Trial design

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

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

3.1.3 Water quality

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

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

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

3.1.4 Pellets

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

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

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

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

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

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

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

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

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

3.1.5 Trash fish/low-value fish

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

3.2 Results

3.2.1 Farm by farm growth and feed utilization

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

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

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

TABLE 5
Farm by farm growth and feed utilization data of red snapper and orange-spotted grouper in farmers' participatory trial, China

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

* FCR could not be calculated due to an error in the trial in that farm and feed type.
** Cost incurred in Chinese Yuan Renminbi (CNY) converted to US$ based on an exchange rate of US$1 = CNY6.66
Note: Values in the same column with different superscripts are significantly different (P<0.05).

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

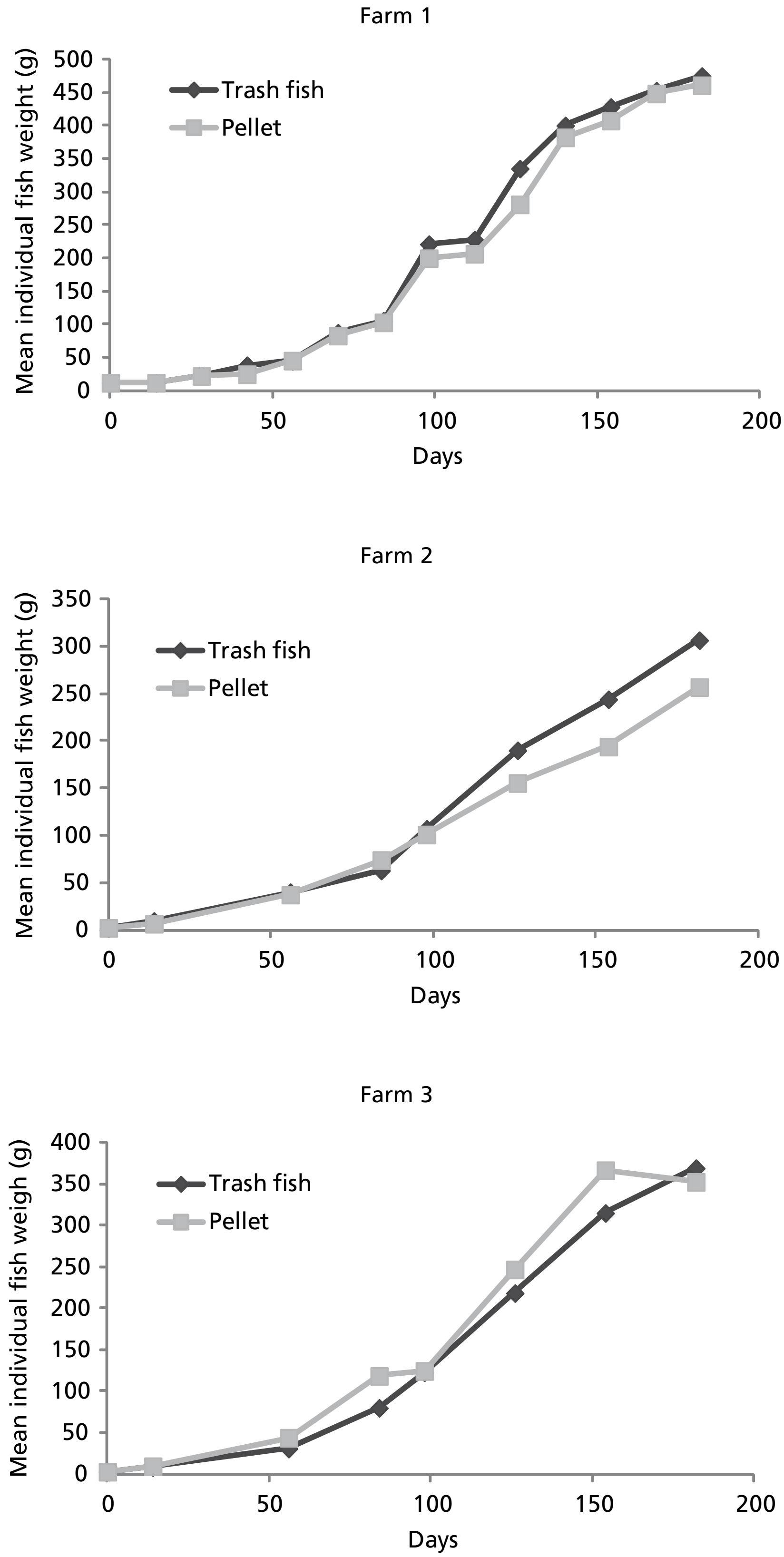
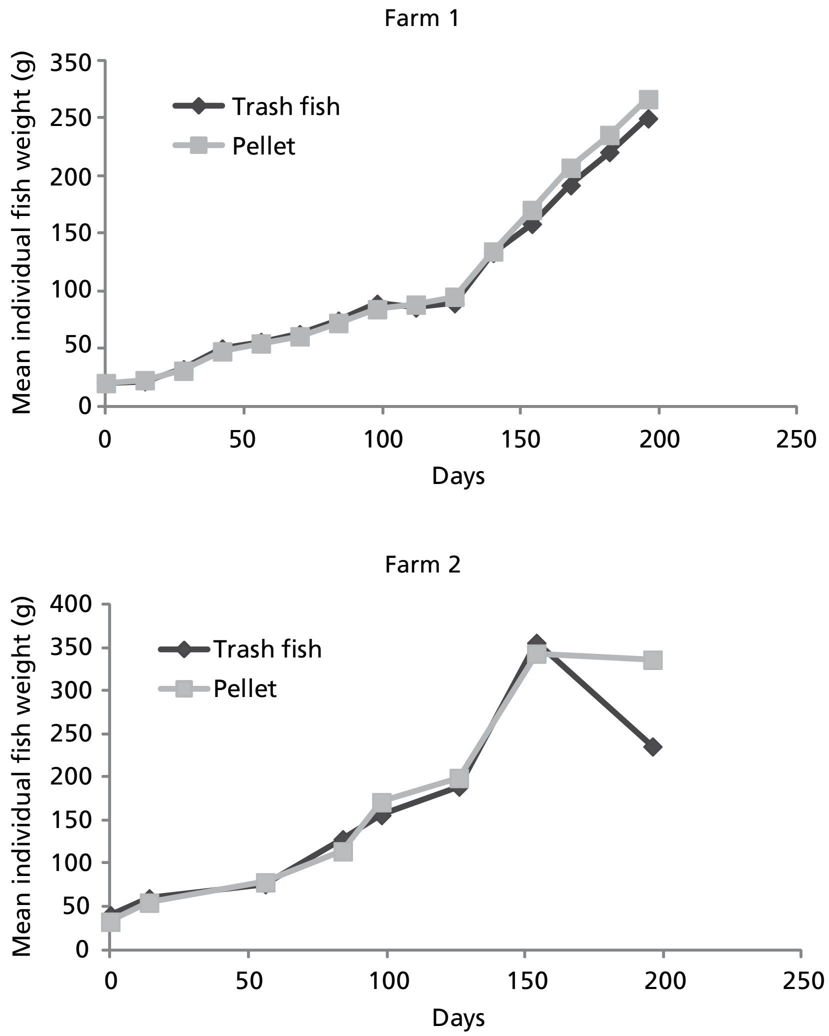


FIGURE 2
Mean weight of orange-spotted grouper fed trash fish/low-value fish or pellets in two trial farms, China



3.2.2 Overall growth and feed utilization

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

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

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

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

3.2.3 Economic performance

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

TABLE 7

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

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

Note: 1US$ = CNY6.66.

3.2.4 Water quality

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

TABLE 8

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

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

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

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

3.2.5 Disease diagnosis and control

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

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

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

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

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

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

TABLE 9
Disease outbreak and control during trial period between April and November 2009, China

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

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

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

3.3 Discussion

3.3.1 Pellet feed quality

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

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

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

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

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

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

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

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

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

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

3.3.2 Characterization of on-farm growth and feed utilization

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

3.3.3 Overall growth and feed utilization

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

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

3.3.4 Economic performance

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

4. FARMERS' PARTICIPATORY TRIAL: INDONESIA

4.1 Materials and methods

4.1.1 Farmers

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

TABLE 10

General characterization of the trial farms, Indonesia

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

4.1.2 Trial design

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

TABLE 11

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

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

*Length, width and depth.

4.1.3 *Water quality*

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

4.1.4 *Pellet feed*

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

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

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

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

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

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

4.1.5 *Trash fish/low-value fish*

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

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

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

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

4.2 Results

4.2.1 Farm by farm growth and feed utilization

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

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

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

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

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

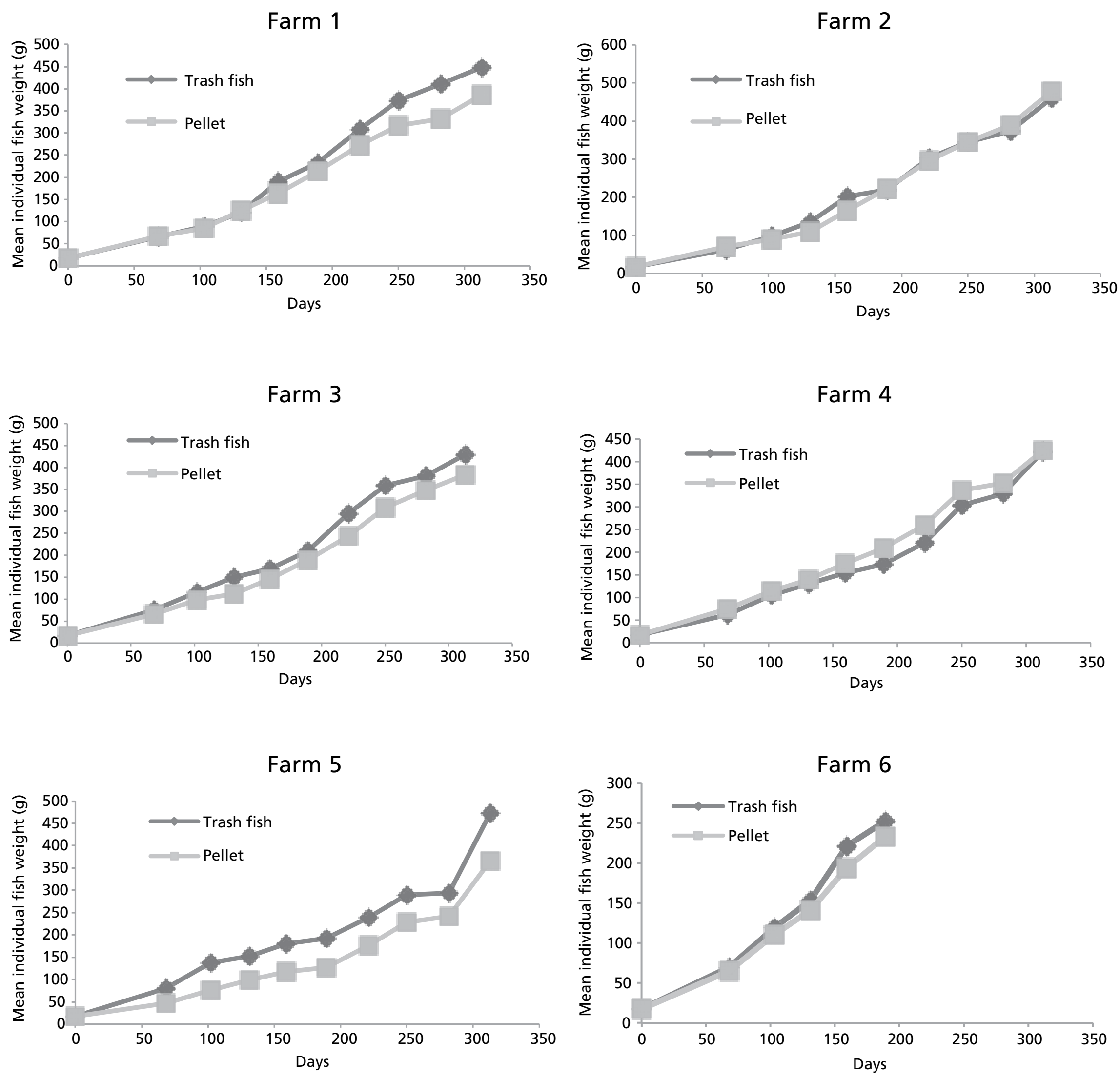
** Cost incurred in Indonesian Rupiah (IDR) converted to US$ based on an exchange rate of US$1 = IDR 9 047.

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

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

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

FIGURE 3
Mean fish weight of brown-marbled grouper fed trash fish/low-value fish and pellets in six trial farms, Indonesia



4.2.2 *Growth and feed utilization*

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

TABLE 15
Overall growth and feed utilization data of brown-marbled grouper in farmers' participatory trial, Indonesia

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

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

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

4.2.3 Economic performance

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

TABLE 16
Feed cost associated with the production of one kilogramme of fish in farmer's participatory trials, Indonesia

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

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

4.2.4 Water quality

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

TABLE 17
Summary of the water quality parameters measured in farmers' participatory trial, Indonesia

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

TOM = total organic matter

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

Courtesy of FAO/M.C. Nandeesha

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

4.2.5 Disease diagnosis and monitoring

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

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

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

4.3 Discussion

4.3.1 Pellet feed quality

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

4.3.2 Growth and feed utilization

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

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

5. FARMERS' PARTICIPATORY TRIAL: THAILAND

5.1 Materials and methods

5.1.1 Farmers

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

5.1.2 Trial design

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

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

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

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

5.1.3 Water quality

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

5.1.4 Pellets

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

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

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

* Length, width and depth;

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

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

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

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

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

5.1.5 Trash fish/low-value fish

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

Marine cages cages in Phang Nga, southern Thailand. In this area, barramundi are mostly cultured in cages.

Courtesy of FAO/Mohammad Hasan

TABLE 20

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

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

5.2 Results

5.2.1 Water quality parameters

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

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

TABLE 21

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

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

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

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

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

Courtesy of FAO/Mohammad Hasan

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

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

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

5.2.2 Farm by farm growth and feed utilization

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

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

TABLE 22

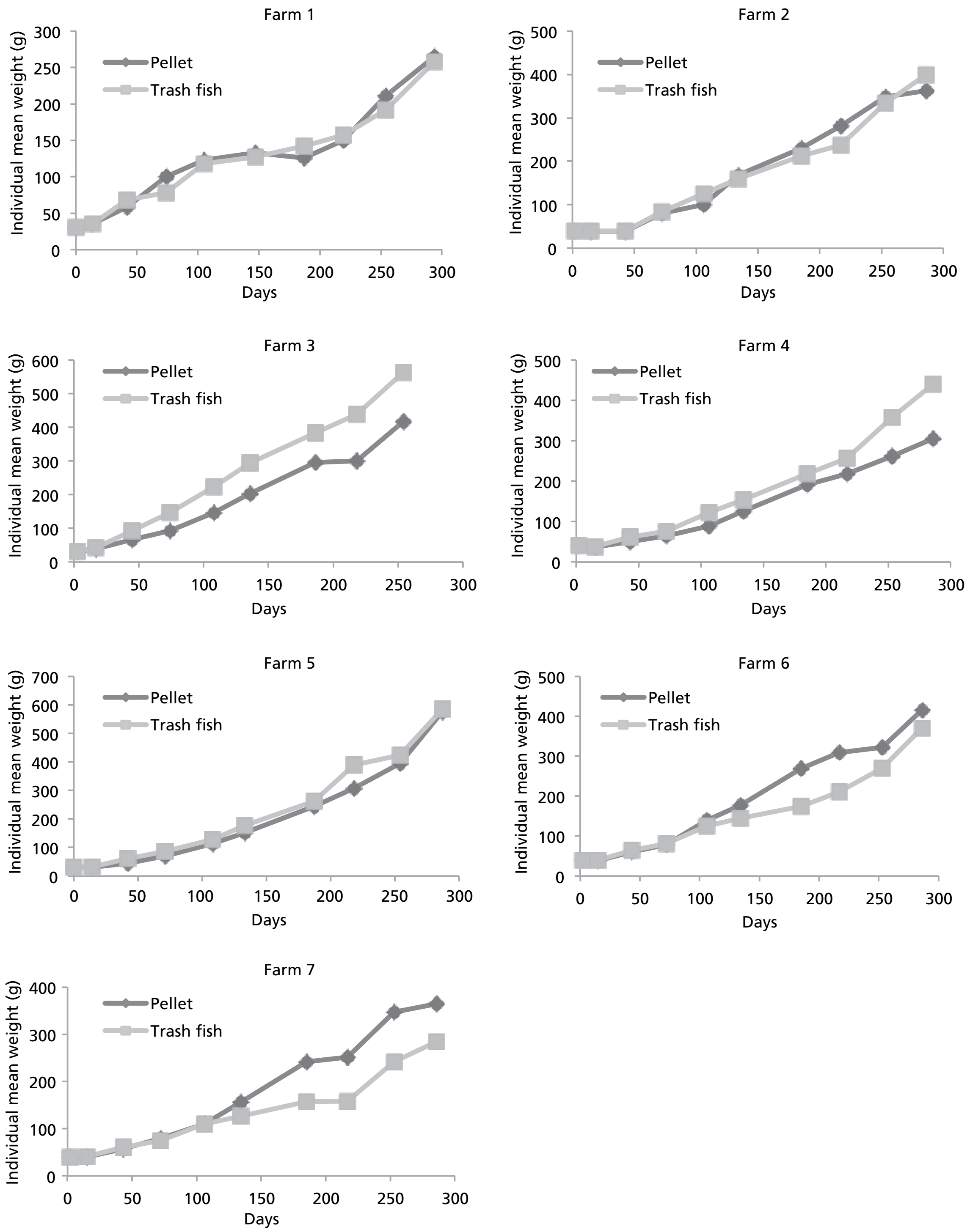
Farm by farm growth and feed utilization data of barramundi in farmers' participatory trial, Thailand

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

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

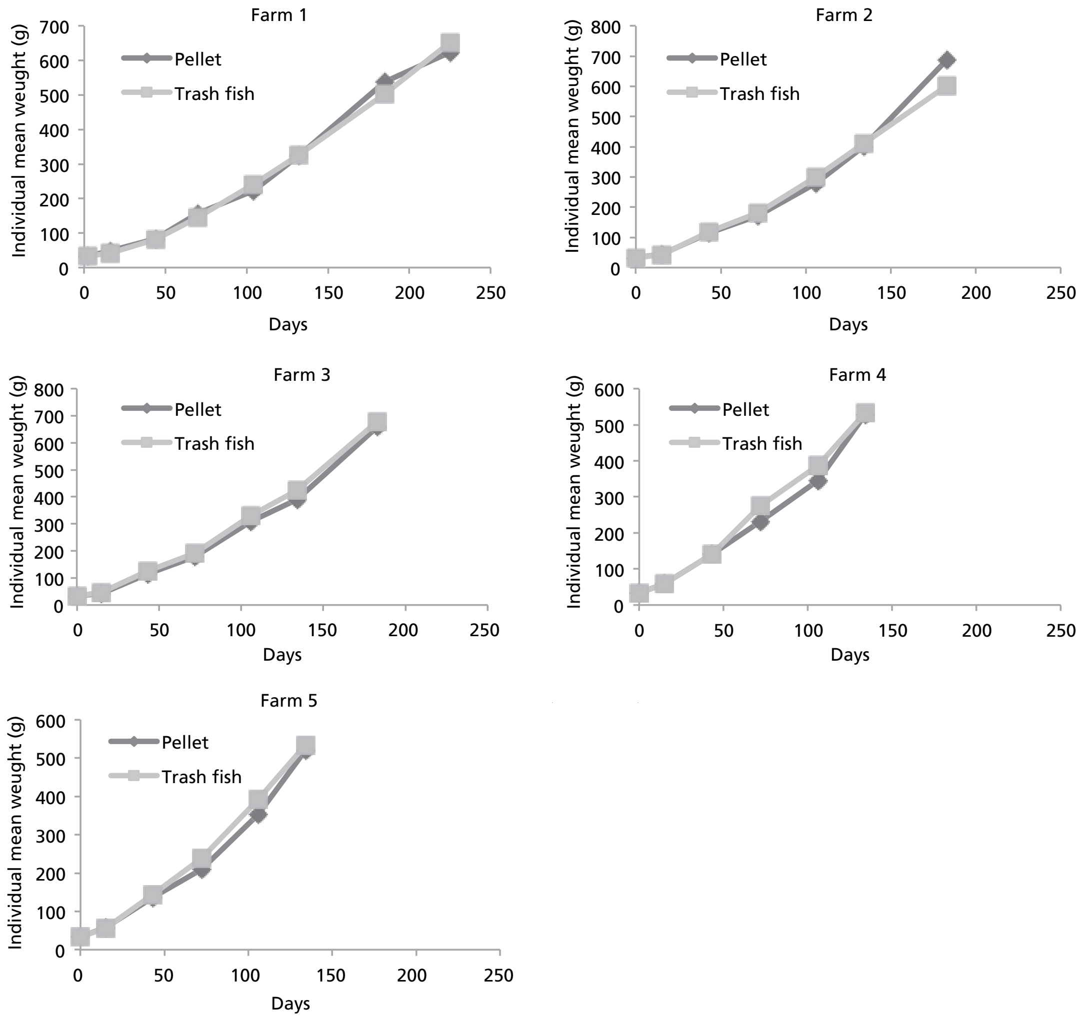
* Cost incurred in Thai Baht (THB) converted to US$ based on an exchange rate of US$1 = THB35.2

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



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

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



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

5.2.3 Overall growth and feed utilization

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

TABLE 23
Farm by farm growth and feed utilization data of brown-marbled grouper in farmers' participatory trial, Thailand

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

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

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

TABLE 24
Overall growth and feed utilization data of barramundi and brown-marbled grouper in farmers' participatory trial, Thailand

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

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

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

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

5.2.4 Economic performance

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

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

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

5.3 Discussion

5.3.1 Water quality

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

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

5.3.2 Pellet feed quality

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

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

5.3.3 Farm by farm growth and feed utilization

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

5.3.4 Overall growth and feed utilization

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

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

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

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

6. FARMERS' PARTICIPATORY TRIAL: VIET NAM

6.1 Materials and methods

6.1.1 Farmers

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

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

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

6.1.2 Trial design

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

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

	Snubnose pompano		Red snapper	
	Pellets	Trash fish	Pellets	Trash fish
Initial weight (g)	5.3	5.3	78.0	78.0
Stocking density (no. of fish/cage)	750 ± 75	750 ± 75	250	250
Stocking density (no. of fish/m^3)	11.9 ± 1.0	11.9 ± 1.0	6.9	6.9

6.1.3 Water quality

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

6.1.4 Pellets

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

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

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

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

6.1.5 Trash fish/low-value fish

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

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

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

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

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

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

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

6.2 Results

6.2.1 Farm by farm growth and feed utilization

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

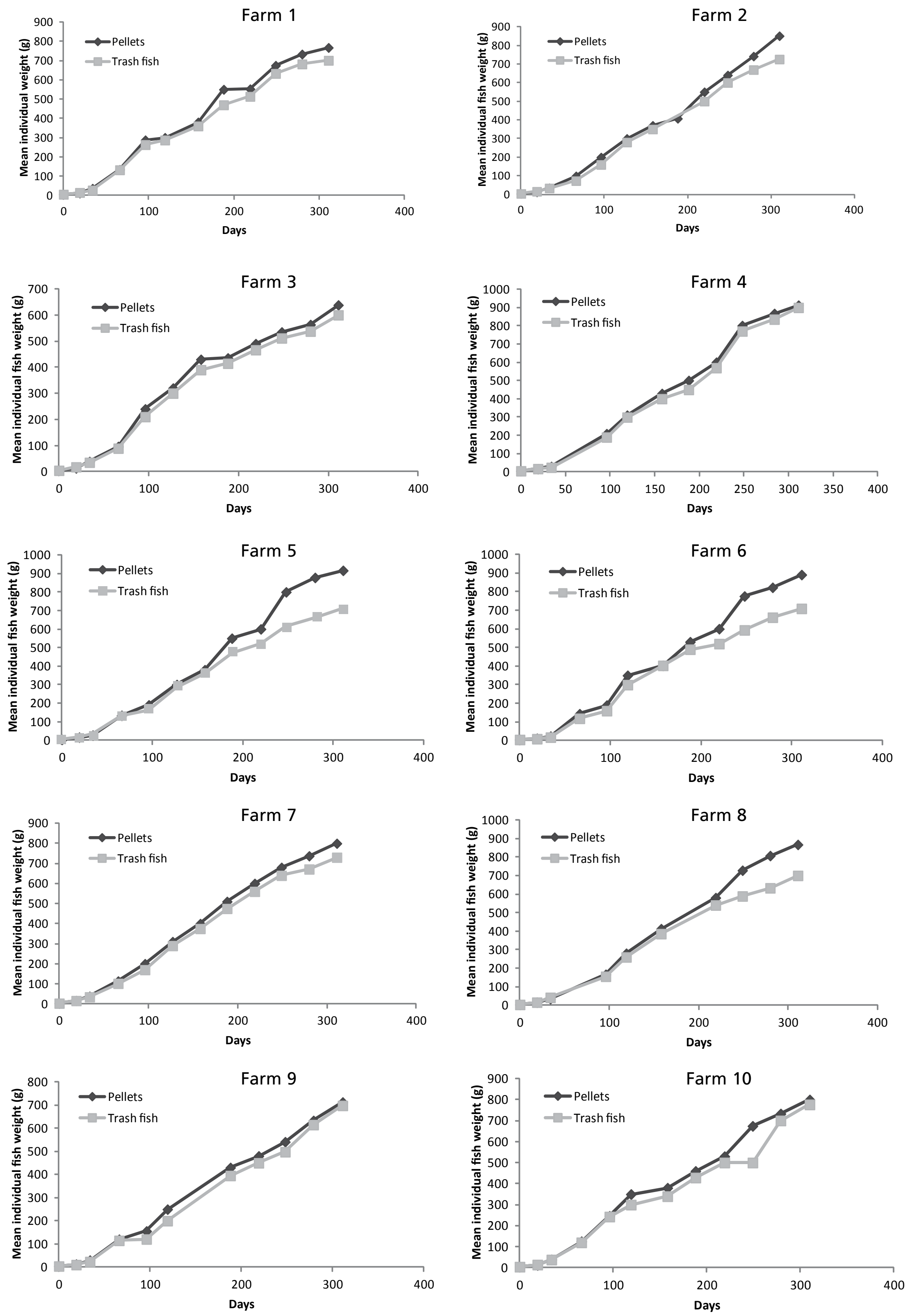
TABLE 31
Farm by farm growth and feed utilization data of snubnose pompano and red snapper in farmers' participatory trial, Viet Nam

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

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

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

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



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

Courtesy of FAO/Mohammad Hasan

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

Courtesy of FAO/Mohammad Hasan

6.2.2 *Growth and feed utilization*

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

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

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

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

6.2.3 *Economic performance*

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

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

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

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

6.2.4 *Water quality parameters*

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

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

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

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

6.3 Discussion

6.3.1 Pellet feed quality

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

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

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

Preparing trash fish/low-value fish for brown-marbled and humpback groupers, Lampung Bay, Bandar Lampung, Indonesia
Courtesy of FAO/Mohammad Hasan

6.3.2 Farm growth and feed utilization

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

6.3.3 Overall growth and feed utilization

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

6.3.4 Economic performance

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

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

7. SYNTHESIS OF THE FOUR COUNTRY STUDIES

7.1 Limitations on comparisons between four country trials

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

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

Courtesy of FAO/Thai Chien

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

7.2 Groupers

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

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

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

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

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

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

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

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

7.3 Red snapper

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

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

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

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

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

7.4 Barramundi and snubnose pompano

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

TABLE 37

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

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

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

7.5 Pellet feeds

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

7.6 Common themes

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

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

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ANNEXURE A

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

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

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

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