9. Indonesian live reef fish industry: status, problems and possible future direction

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Background

Live reef food fish (LRFF) has been traditionally consumed by Chinese people, especially among the southern coastal populations. For centuries, this tradition has existed because fish is considered a symbol of prosperity and good fortune in Chinese culture. Yeung (1996) and Cheng (1999) in Chan (2000) pointed out that fresh marine fish, especially the high-valued live reef food fish, has an important cultural and social role for special occasions, festivals and business dinners. With the rapid growth in population and rise in household income, demand for fresh marine fish also increases significantly. This, in turn, leads to imports from many countries, such as the Philippines, Thailand, Australia and Indonesia. With high demand and extremely high prices expected, these marine species are widely exploited. The LRFF trade has been become a global as well as regional concern. Available evidence suggests that LRFF have been over-exploited in many parts of Southeast Asia, such as in the Philippines and Indonesia. An important species of concern is the grouper fish, known as '*Kerapu*'.

One of the ecological functions of coral reef is as a habitat for fish, such as the coral fish group. Indonesia has a coral reef area of 85 000 sq. km (about 18% of the world's coral reef area) and thus has the potential to become one of the main producers of live reef fish. Trade in grouper fish has become an important economic activity in the Asia–Pacific, involving more than 20 producing countries, with an estimated commercial value of US$350 million a year. The main market for this product is countries in East Asia, especially Hongkong and the Peoples Republic of China.

Sustainability of the live grouper fish industry is threatened by bad management. Significant price increases on the international market lead to intensive and uncontrolled fishing pressure on a particular species. Many fishers use prohibited devices, such as explosive material and cyanide poison, causing at degradation of the coral reefs. A World Wildlife Fund (WWF) report (Sumaryono, 2002), classified Indonesian coral reefs as hardly damaged (42%), damaged (28%), with the rest in normal to good condition. The grouper is considered a 'sedentary species' which lives in a particular habitat and takes a long time (5–10 years) to regenerate. Hence, the impact from improper fishing practices will be serious degradation of the environment, even leading to extinction of particular species in certain areas.

This paper will review the current status and problems, and explore possible future directions for the live reef fish industry in Indonesia.

Structure of Indonesian fisheries

Indonesia is a maritime country; with 5.8m sq. km of marine waters. This environmental characteristic has led to important marine economic activities, such as fisheries, tourism, mining and energy, transportation and other industries which together contribute to 20% of the national GDP.

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The fisheries sector, in particular, has potential to be developed. Recently, the sector has contributed about 1.8% of national GDP. Based on fish supply data in 2000 (Table 1) Indonesia's fish production has been dominated by capture activities (79.3%), while aquaculture contributed 20.7% of total production.

Table 1. Structure of fish supply in Indonesia, 2000.

Category	Environment	Capture technology/ Culture environment	Production (ton)
Capture (79.3%)	Marine (74.5%)	Trawler-like	737 219
		Purse seine	609 243
		Gillnet	829 376
		Hook and lines	829 408
		Traps	226 852
		Other	242 475
	Inland (4.8%)	Gillnet	101 360
		Hook and lines	49 107
		Other	78 458
Culture (20.72%)	Freshwater (7.66%)	Pond	214 393
		Cage	60 375
		Paddy field	93 063
	Marine and Brackishwater (13.06%)	Pond and cage	627 131
Total			**4 802 153**

Source: Data from the Directorate General of Aquaculture Fisheries (2002) and Directorate General of Capture Fisheries (2002).

Fish production during the period 1999–2002 increased in all sectors except for the inland culture fishery which showed a small decline during this period. Overall, capture and aquaculture production increased by 3.2% and 8.9%, respectively. Details of Indonesian fish production are shown in Table 2.

Table 2. Capture fisheries and aquaculture production in Indonesia (1999–2002) ('000 tons).

No.	Category	1999	2000	2001	2002*	Rate of increase (%)
1.	Capture	4 010.1	4 112.4	4 246.6	4 405.2	3.2
	— marine	3 682.4	3 807.2	3 940.0	4 097.8	3.6
	— inland	327.6	305.2	306.6	307.4	–2.1
2.	Culture	883.0	995.0	1 076.8	1 140.0	8.9
	— marine	136.0	197.1	221.0	260.0	24.9
	— brackish water	412.9	430.0	454.7	472.0	4.6
	— pond	177.6	214.4	222.8	226.0	8.7
	— cage	32.3	25.8	39.3	40.0	11.4
	— net-cage	29.5	34.6	40.7	42.0	12.7
	— paddy field	94.6	93.1	98.2	100.0	1.9
	Total	**4 893.1**	**5 107.4**	**5 323.3**	**5 545.2**	**4.3**

Source: Central Bureau of Statistics (2003).

* Temporary figures.

During 1999–2002, the 'catching power' was evenly balanced between non-boat engine and boat/vessel. In spite of this, non-boat engine activities fell slightly (–2.19%); from 241 517 units in 1999 to 225 890 units in 2002. During the same period, catching power of boat/vessel increased (1.69%); from 214 413 units in 1999 to 225 440 units in 2002, probably due to the increase of larger vessels (≥50 GT weight) (Table 3).

Table 3. Structure of capture fisheries in Indonesia, 1999–2002 (in units).

Category	1999	2000	2001	2002[1]	Rate of increase (%)
Non-boat engine	241 517	230 867	228 730	225 890	–2.2
Boat/vessel	214 413	218 691	221 600	225 440	1.7
— Out-boat engine	124 043	121 022	122 027	123 170	–0.2
— Vessel	90 370	97 669	99 573	102 270	4.2
<5 GT	57 768	65 897	66 680	67 720	5.6
5–10 GT	18 850	19 460	19 570	19 570	1.5
10–20 GT	6 792	5 599	5 810	5 810	–3.2
20–30 GT	3 439	2 974	3 340	3 340	0.6
30–50 GT	1 516	1 543	781	1 140	–0.6
50–100 GT	1 038	1 129	1 602	2 030	25.8
100–200 GT	756	741	1 295	1 680	34.2
>200 GT	211	326	495	520	37.1

Source: Central Bureau of Statistics (2003).

Remark: [1] Temporary figures.

Table 3 also shows that capture fisheries in Indonesia, in general, are categorised into traditional/small-scale fisheries and industrial fisheries. Small scale fisheries are characterised by non-boat engines, out-boat engine and in-boat engine with a capacity less than 5 GT. This type of fishery is also associated with fishermen who have a great deal of experience and a low level of education.

Aquaculture in Indonesia has developed enormously. The rate of increase varies from 3.7% to 74.0%. The largest development was in marine-water aquaculture and the smallest was in brackish water aquaculture. Table 4 shows the production performance of aquaculture from 1999 to 2002.

Table 4. Structure of culture fisheries in Indonesia, 1999–2002.

Category	1999	2000	2001	2002[1]	Rate of increase (%)
Marine water (Unit)	48 775	122 776	142 690	220 000	74.0
Brackish water (Unit)	393 196	419 282	438 101	438 000	3.7
Pond (ha)	65 889	77 647	82 500	82 500	8.2
Cage (ha)	34	76	80	80	42.9
Net-cage (Unit)	32 144	37 413	72 280	60 200	31.0
Paddy-field (ha)	135 057	157 346	150 680	160 800	6.3

Source: Central Bureau of Statistics (2003).

[1] Temporary figures.

Table 5 shows trade of the Indonesian fisheries product. This table shows that fisheries have contributed substantially to foreign earnings, in the sense that export value is greater than import value. In addition, the export value tends to increase while the import value tends to fall.

Table 5. Trade in Indonesian fisheries products (2000–2002) (US$1,000).

Category	2000	2001[1]	2002[1]	Rate of increase (%)
Export	1,674,073.5	1,631,898.6	2,432,632.5	23.3
Import	111,387.3	103,616.0	60,300.6	–7.0

Source: Central Bureau of Statistics (2003).

[1] Temporary figures.

The other important indicator for Indonesian fisheries is employment. Fisheries directly employ about five million people — three million fishermen and two million fish farmers (Table 6) and indirectly employ more than twice that number.

Table 6. Employment in Indonesian fisheries by sector (1999–2002).

No.	Category	1999	2000	2001	2002[1]	Rate of increase (%)
1.	Capture	2 890 054	3 104 861	2 956 200	2 967 000	1.0
	— Marine	2 409 029	2 486 456	2 496 200	2 506 000	1.3
	— Inland	481 025	618 405	460 000	461 000	1.1
2.	Culture	1 901 309	2 181 650	2 190 920	2 193 600	5.1
	— Marine	10 316	29 604	39 880	40 000	74.0
	— Brackish water	264 365	309 281	324 380	324 400	7.3
	— Pond	1 251 321	1 268 860	1 266 740	1 268 000	0.4
	— Cage	53 842	54 237	54 890	56 000	1.3
	— Net-cage	13 179	9 287	15 600	15 200	12.0
	— Paddy field	308 286	510 381	489 430	490 000	20.5
	Total	**4 791 363**	**5 286 511**	**5 147 120**	**5 160 600**	

Source: Central Bureau of Statistics (2003).

[1] Temporary figures.

Fisheries also play an important role in enhancing food security in the region, since fish is generally consumed by poor households. During 1999–2002 annual fish consumption increased from 20.7 to 22.8 kg/head (Table 7).

Table 7. Fish consumption in Indonesia, 1999–2002.

Category	1999	2000	2001	2002[1]	Rate of increase (%)
Total (ton)	4263.48	4506.93	4687.64	5009.28	5.5
Per capita (kg/head/yr)	20.71	21.57	22.44	22.84	3.3

Source: Central Bureau of Statistics (2003).

[1] Temporary figures.

Government policy on fisheries can be divided into four phases. During the first phase (1968–1993) the fisheries sector focused on increasing the domestic consumption and export earnings, supplying raw material for industry and poverty alleviation. During the second phase (1994–1997), the policies changed to focus on development of human resources, increased

supply and distribution of fisheries products, employment opportunities and development of the industry. In the third phase (1997–1998) fisheries policies were part of the government's efforts to overcome the country's monetary and economic crisis by fostering export earnings through a program known as PROTEKAN (Program Peningkatan Ekspor Perikanan).

In recent years the fisheries sector has been linked closely with the government's decentralisation policy. In this phase, fisheries policies have been particularly aimed at promoting participatory management, the role of women in fisheries, and institutions and investments for fishers and fish farmers. As well, policies are also aimed at maintaining the quality of aquaculture, increasing value adding of the fisheries product and providing better infrastructure, such as roads, transport and communication.

Structure of the Indonesian live reef fish industry

Since the last decade, live reef fish have become a high-value commodity, both for domestic consumption and on the international market. However, statistics on production, import and export are not recorded as part of national statistical-record-keeping by Indonesia Fisheries. Coral reef fish are likely to be distributed where there are coral reefs or at least near to that habitat where they spend most of their life cycle. In the western part of Indonesia, coral reef fish are located in the Malacca Strait (Nanggru Aceh Darussalam, East Sumatra and Riau Archipelago), the Sunda Strait (Lampung and Jakarta Bay), the north coast of East Java, and the Bali and Lombok Straits. In the east, they are found in north Sumbawa (*Nusa Tenggara Timur*), Selayar, Semuna and Tanakeke islands (South and Southeast Sulawesi), North Maluku and Arafura Sea (Papua).

Fisheries production in Indonesia is comprised of fishing and aquaculture activities. Fishing operates throughout the year, using a demersal fishing unit, such as long lines, traps, gillnets and scoop nets. Illegal fishing units are also operated by fishers using explosive and chemical devices (cyanide). The fishing industry is predominantly comprised of small-scale fishers. Aquaculture activities in the forms of cage culture (*Karamba Jaring Apung)*, pen culture (*Karamba Tancap*) and brackish water ponds (*Tambak*) were operated from a small-scale to a commercial scale.

Most production of grouper fish came from fishing activity, which accounted for 45 231 ton (1999) and 55 457 ton (2002). During 1999–2002, total production increased by 7.5%. Production from fishing over the period increased by 3.8% while aquaculture production increased by more than 100% over the same period.

Illegal fishing operations have caused problems of serious environmental degradation (Lowe, 2004). Significant losses of coral reefs have occurred. Studies in several sites of eastern Indonesia (Basuki *et al.*, 2004) indicated that the economic loss can reach up to IDR 80.47 billion per year (Table 9).

Table 8. Grouper fish production in Indonesia, 1999–2002.

No.	Category	Production (ton)					Change (%)
		1998	1999	2000	2001	2002	
1.	Aquaculture[1]	na	1 759	6 879	3 820	7 057	100.4
2.	Capture[2]	43 766	43 472	48 422	48 516	48 400	3.8
	Total	–	45 231	55 301	52 336	55 457	7.5

Source: [1] Directorate General of Aquaculture Fisheries (2004).
[2] Directorate General of Capture Fisheries (2004).

Table 9. Estimated economic loss due to damaged coral reef, eastern Indonesia (2004).

Region	Area of coral reef (sq. km)	Fish production per sq. km of coral reef by condition (ton)		Estimated loss[3] (Billion IDR/year)
		Good[1]	Poor[2]	
Pangkep, Sulawesi Selatan	374	11 220	1 870	7.8
Selayar, Sulawesi Selatan	1098	27 450	5 490	18.3
Buton, Sulawesi Tenggara	1402	35 050	7 010	23.4
Raja Ampat, Papua	1299	32 475	6 495	21.7
Biak, Papua	424	10 600	2 120	7.1
Sikka, Nusa Tenggara Timur	128	3200	640	2.1
Total	**4725**	**119 995**	**23 625**	**80.5**

Source: data processed rom Basuki *et al.* (2004).

Notes: [1] Fish production per sq. km of coral reef assumed to be 30 ton.
[2] Fish production per sq. km of coral reef assumed to be 5 ton.
[3] Price of fish is assumed to be IDR. 16.7 million per 20 ton.

Evidence on the island of Komodo, synthesised by Mous *et al.* (2002) indicates that as the live reef food fish trade began in that region in the late 1990s, the coral fish (groupers and napoleon wrasse) have been heavily exploited, both by cyanide and hook-and-line fishing devices. Further, they found that the live reef fish food trade has threatened coral reef biodiversity through three related mechanisms, namely: (1) physical damage of coral reef resources; (2) adult fish stock extremely vulnerable to overfishing; and (3) disappearing fingerlings of the tradeable targeted coral fish. [Details of the explanation can be found in Johannes and Riepen (1995), Erdmann and Pet-Soede (1996) and Pet and Pet-Soede (1999)].

Although aquaculture makes a relatively low contribution to total production, it increased significantly high during the period 1999 to 2001. Among those coral fish produced, the species with the most potential for aquaculture in Indonesia are shown in Table 10.

Table 10. Grouper species with aquaculture potential in Indonesia.

Local name	English/Commercial name	Scientific name
Kerapu Bebek/Tikus	High finned grouper, Humpback grouper Barramundi cord Polka dot grouper	*Cromileptes altivelis*
Kerapu Macan	Brown marble grouper Carpet cord Flowery cord Blotchy rock cord	*Ephinephelus fuscoguttatus*
Kerapu Malabar	Estuarine grouper	*Ephinephelus malabaricus*
Kerapu Lumpur	Orange spotted grouper Green grouper	*Epinephelus coioides* *Epinephelus tauvina suillus*
Kerapu Batik		*Epinephelus microdon*
Kerapu Sunu Lodi Halus	Leopard coral trout Blue spotted sea bass	*Plectropomus leopardus*
Kerapu Sunu Lodi Kasar	Barred-cheek coral trout Spotted coral trout	*Plectropomus maculatus*

Source: Sunaryanto *et al.* (2002), modified.

In most cases, a marine environment was used to grow coral fish. Among the coral fish, grouper is the species which fish farmers preferred for aquaculture. Although there was no available documented data, about 90% of grouper fish farmers operate their activity in cages set in seawater. This is because they are relatively familiar with the technical knowhow of this type of aquaculture and also because of the relatively high price of these species (Table 11).

Table 11. Imported live reef food fish from Indonesia in Hongkong, 1998.

Fish species	Production		Value of production	
	(kg)	(%)	('000 US$)	(%)
Kerapu tikus/bebek (*Cromileptis altivelis*)	13 714	0.066	424	0.321
Ephinephelus lanceolatus	280	0.001	4	0.004
Kerapu sunu (*Plectopormus spp.*)	640 156	3.068	12,096	9.140
Kerapu macan (*E. fuscoguttatus*)	4 860 318	23.293	32,245	24.365
Napoleon wrasse (*Chelinius undulatus*)	1796	0.009	33	0.025
Sub Total	**5 516 264**	**26.000**	**44,802**	**34.000**
Scaridae	9984	0.048	113	0.085
Centropomidae	1 346 073	6.451	3,550	2.682
Other coral fishes	13 994 042	67.065	83,875	63.378
Total	**20 866 363**	**100.000**	**132,340**	**100.000**

Source: Directorate General of Aquaculture Fisheries, 2002 (processed).

Notes: *Scaridae* is a herbivorous coral fish, while others are carnivorous.

Table 11 shows that the volume of grouper fish imported from the total live reef fish food trade (rows 1 to 5) was equal to 5 516 264 kg and represented 26% of the total imported life reef fish volume, valued at US$44,802,000 or equivalent to 34% of the total value of the traded life reef fish sold in Hongkong.

Status, problems and constraints for development

Capture fisheries

Live reef food fish (LRFF) is an attractive source of animal protein, income and employment for most of the fishing community living near coral reefs. Traditionally, fishers operate demersal fishing units, such as long lines, traps, gillnet and trawler-like vessels. However, with the introduction of the live reef food fish trade, destructive fishing activity, such as illegal fishing with explosive devices, compressors and chemicals is becoming common. This situation has rapidly had a harmful effect for most fishers and also for the coral reef environments. Fishing communities along the shores of Indonesia's more remote islands are experiencing the surveillance, enforcement and sharp criticism associated with cyanide. Both Indonesian bureaucrats and national and international conservationists focus on intervention at the community level. The fishers were being blamed for operating illegal fishing units. However, studies by Lowe (2004) in the Togian islands of Sulawesi questioned why fishers who were experienced in traditional fishing methods would move to destructive fishing devices. He proposed several reasons for such a change in fishers' habit. One reason is the fact that live reef food fish provide high profits and, through the use of cyanide, provide a way for the younger generation to obtain money to build houses and establish new, independent families in a short time. Illegal fishing methods such as cyanide also have a status that is appealing to young people. Cyanide fishers demonstrate their wealth and

status by controlling outboard motors and they also have the money to smoke expensive cigarettes and wear fashionable new clothes. Lowe's study also indicated that between 15 and 80% of fishing communities around the islands operate such illegal fishing devices.

Geoffrey Muldoon

Grow-out cages, Komodo, Indonesia. Evidence suggests that live reef food fish have been overexploited in many parts of Southeast Asia.

Aquaculture

Rimmer (2002) reviewed the status of grouper production technologies in the Asia–Pacific region with a special focus on the need for grouper aquaculture research for further development. He highlighted the status of grouper hatcheries, rearing and grow-out technologies. In Indonesia, several species of coral reef fish have been successfully cultured. Among them, grouper (*kerapu*) is the species which farmers prefer. Species commonly cultured are shown in Table 12. Culture techniques for grouper in Indonesia include earthen pond (brackish water environment) culture and cage (marine water environment) culture.

Table 12. Development of grouper hatcheries by province and production scale (1999–2002).

Province	Number of grouper hatcheries by production scale											
	1999			2000			2001			2002		
	small	med.	large	small	med.	large	small	med.	large	small	med.	large
Bali	0	1	0	3	1	0	110	4	0	51	4	0
Lampung	0	1	1	0	1	2	1	1	3	0	2	4
East Java	0	0	2	0	0	3	1	0	3	1	1	5
Total	0	2	3	3	2	5	112	5	6	52	7	9

Source: Kawahara and Ismi, 2003.

At the early stage of development, juveniles were mainly supplied from the wild. Recently, several species have been successfully produced in both government and private hatcheries.

Hatcheries

Over the past five years, the number of grouper hatcheries has grown significantly, especially in Gondol, Bali (Table 12). However, during 2001–2002, the number of small-scale grouper hatcheries fell. This was because of the significant fall in seed prices due to overproduction, bad management of larval rearing, and low adoption of new grow-out technologies. In response, through the Agency for Assessment and Implementation Technology (*Badan Pengkajian dan Penerapan Teknologi, BPPT*), the government has developed the national strategy for grouper research priority (*Riset Unggulan Strategi Nasional Kerapu, RUSNAS-Kerapu*).

Notes: Hatchery scale: small, number of workers <5 persons; med., number of workers 5–9 persons; and large, number of workers ≥10 persons.

Typical financial performance of small-scale hatchery production is illustrated in Table 13. The hatchery was operated using two tanks with a capacity of 20 ton. Eggs were bought from the government hatchery. Hatchery producers have to buy natural food, artificial feed, artemia, vitamins and medicines. As shown in Table 13, the higher percentage of operating costs were for purchasing fish eggs (46.6%) and artemia (26.1%). The profit per production cycle (2 months) was expected at IDR 13.78 million; while the calculated ratio of return over cost (R/C ratio) was 1.28.

Table 13. Financial analysis of small-scale grouper hatchery in Batam, Riau province, 2002.

No.	Items	Values (IDR)	Percentage (%)
1.	Cost		
	a. investment cost		
	— 2 tanks @ 2 × 5 m	7,000,000	
	— fibre glass 2 pieces @ 2 m	3,000,000	
	— high blower	2,000,000	
	— other fisheries equipment	100,000	
	b. Fixed cost (depreciation)		
	— tank	700,000	6.5
	— fibre glass	600,000	5.6
	— high blower	400,000	3.7
	— other fisheries equipment	20,000	0.2
	c. Variable Cost		
	— Fish eggs: 2,000,000 @ IDR 2.5	5,000,000	46.6
	— Fertilisers	200,000	1.9
	— Artemia: 4 canned @ IDR 700,000	2,800,000	26.1
	— Vitamines and medicines	500,000	4.7
	— Labor: 1 person @ IDR 250,000 × 2 months	500,000	4.7
	d. Total Cost	10,720,000	100.0
2.	Total Revenue	24,500,000	
3.	Profit	13,780,000	
4.	R/C Ratio	1.28	

Source: Manadiyanto *et al.* (2002).

Although hatchery production can be regarded as successful, hatchery producers face problems of broodstock management, disease and other health issues, supply of skilled labour, technological know-how, development of economical and low pollution feeds and marketing.

Grow-out

As explained earlier, grow-out production systems to produce consumable size grouper fish used both brackish water (*tambak*) and marine water environments (cages). However, in the case of Indonesia, more than 90% of grow-out systems used cages in marine water. The most popular size cage was 3 × 3 sq. m and 8 × 8 sq. m. The life span of the cages varies from 2 to 4 years. New technology, known as 'Polar Cycle' is able to expand the life-span of the cage but this technology has not yet been applied by fish farmers due to higher investment cost. Table 14 shows a typical financial performance of small-scale grouper cage production.

As illustrated in Table 14, grouper seed and feed accounted for 63.4% of the total cost. The calculated profit received by the fish farmer was IDR 15.02 million/10 months with a R/C ratio of 1.29.

The following problems were associated with the grow-out production system: (1) regional development; (2) technological know-how; (3) certification and standardisation of seed; (4) economical and unpolluted artificial feed; (5) institutional and legal issues; (6) seed capital; (7) disease and other health issues; (8) skilled-labor; (9) markets, and; (10) 'land' use conflicts.

Table 14. Financial analysis of small-scale grouper cage production in Batam, Riau province, 2002.

No.	Items	Values (IDR)	Percentage (%)
1.	Cost		
	a. Investment Cost		
	— Floating cage net (size: 3 × 3 × 1.5 m; 4 holes per unit)	12,000,000	
	— Other fishery equipment	750,000	
	b. Fixed Cost (Depreciation)		
	— Floating cage net	4,000,000	17.2
	— Other fishery equipment	1,500,000	6.5
	c. Variable Cost		
	— Grouper seeds (Tiger grouper): 1200 units @ IDR. 8,000	9,600,000	41.4
	— Pakan: 3000 kg @ IDR 1,700/kg × 10 months	5,100,000	22.0
	— Labor: 1 person @ IDR 30,000/month × 10 months	3,000,000	12.3
	d. Total Cost	23,200,000	100.0
2.	Total Revenue	38,220,000	
3.	Profit	15,020,000	
4.	R/C Ratio	1.29	
5.	Break Even Point		
	— Production (kg)	344.21	
	— Price (per kg)	38,051	

Source: Manadiyanto *et al.* (2002).

The market

Hongkong, the mainland of China (southern part), Taiwan and Singapore are considered the main markets for live reef food fish. Indonesian production is yet to meet export demand, due to fluctuations in supply (Table 7). Grouper production has depended on capture more than culture activities. Although there is a domestic demand for grouper in Indonesia, it is relatively small and only from the big restaurants in capital cities. Figure 1 shows the typical marketing distribution for live reef food fish from Indonesia.

In most cases, the structure of the live reef food fish market is an olygopsony (ie, occupied by only two or three traders). Studies carried out by Manadiyanto *et al.* (2002) revealed that in the Riau province, 90 per cent of the grouper market was occupied by four traders who frequently acted as collectors, exporters and even wholesalers. A similar pattern was observed in Lampung, Jakarta and the eastern part of Indonesia. This creates a situation where producers have little say in setting the price.

Fish produced either by capture or culture activities are gathered by collectors or traders in the producing area using carrier vessels. In practice, producers have been tied by collectors paying in advance for their estimated production. While producers do not have access to price information, traders hold all the current information regarding supply and demand for a particular species. So, producers are in a weak bargaining position.

The institutions which should be involved in the export of fish products are the Marine and Fisheries Services at regional level, the Regional Industrial and Trade Services, the *Laboratorium Pembinaan dan Pengujian Mutu Hasil Perikanan* (LPPMHP), Fish Quarantine and Trade Immigration. However, given the situation described above, the role of these institutions is unclear.

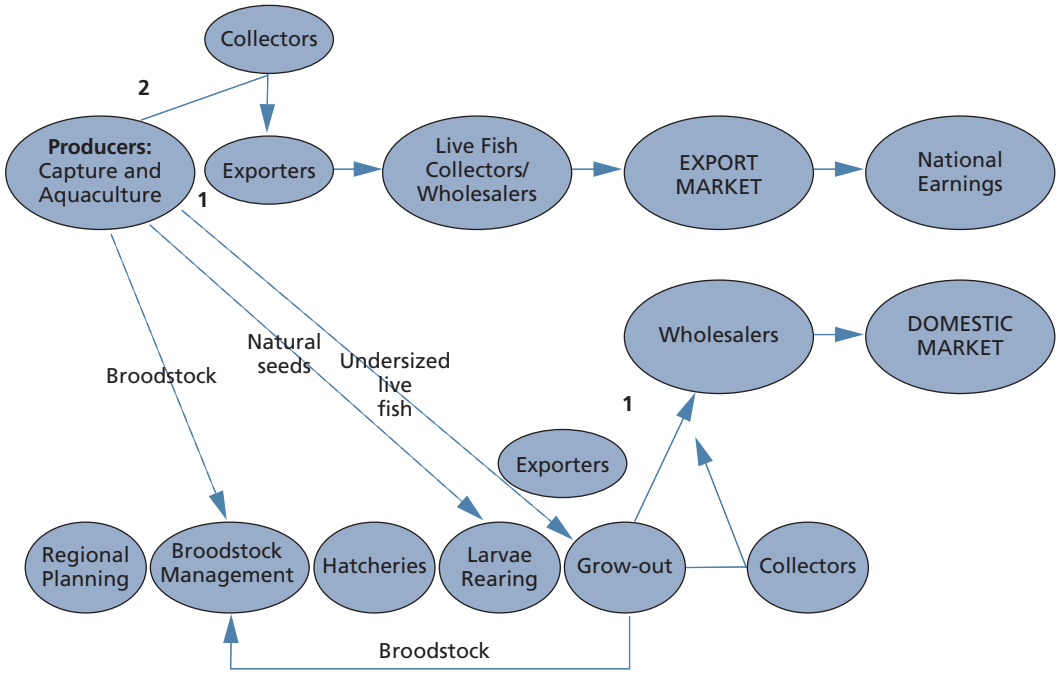

Figure 1. Typical marketing channels of the live reef fish in Indonesia (Modified from Sumaryono, 2002). 1 and 2 represent marketing channel for live reef fish from capture and aquaculture fisheries, respectively.

Studies by Manadiyanto *et al.* (2002) showed the marketing margin of live grouper in Batam, Riau province, is significantly higher for humpback grouper (*kerapu bebek*) followed by brown marble grouper (*kerapu macan*), leopard coral trout (*kerapu sunu*) and green grouper (*kerapu lumpur*). Table 15 shows the details.

Table 15. Marketing margin of live grouper in Batam, Riau province, 2002.

No.	Description	Value according to species (IDR)			
		Kerapu bebek/tikus	Kerapu macan	Kerapu sunu	Kerapu lumpur
1.	Fisher				
	— Producers' price (IDR/pc.; size 20)	20,000	15,000	15,000	10,000
2.	Collector/trader				
	— Buying price (IDR/pc; size 20)	20,000	20,000	15,000	15,000
	— Maintenance and other cost (IDR/pc)	80,000	31,000	35,000	25,000
	— Selling price (IDR/pc; size 20)	135,000	90,000	90,000	75,000
	— Marketing margin (IDR/pc)	115,000	70,000	75,000	65,000
	— Profit (IDR/pc)	35,000	39,000	40,000	40,000

Source: Manadiyanto *et al.* (2002).

The following problems were associated with marketing of live grouper: (1) market intelligence; (2) market access; (3) market development, and (4) harmonised standards for the live reef food fish trade, for example, in terms of marketable size of fish and its quality.

Possible future direction

The main issue for the live reef food fish trade in relation to capture activity is the practice of illegal fishing. A likely future direction for better capture management of live reef food fish will involve working with main stakeholders, in particular fishing grounds and support development of live reef food fish aquaculture. As well, promotion of fair trade should be initiated.

Concluding remarks

This paper has summarised the status, problems and possible future direction of the live reef food fish trade in Indonesia. Evidence of illegal fishing of the main target live reef food fish exists in several fishing grounds in Indonesia. On the aquaculture side, although hatchery technology and grow-out systems have been practised by fish farmers, new technology should be investigated in order to meet local as well as export demand.

Acknowledgments

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References

Basuki R., Hartono T.T., Mahasin dan I.N. and Tarigan Z. (Eds) 2004 Pedoman Umum Pengelolaan Sumberdaya Terumbu Karang Berbasis Masyarakat. Coremap II Project, DKP — World Bank. Jakarta. 68 halaman. Unpublished.

Central Bureau of Statistics 2003 Fisheries and Aquaculture Statistics. Central Bureau of Statistics, Indonesia.

Chan N.W.W. 2000 An integrated attitude survey on live reef food fish consumption in Hongkong. WWF for Nature Hongkong. p. 101.

Directorate General of Aquaculture Fisheries 2002 Handbook of the Aquaculture Fisheries Statistics of Indonesia 2002. Directorate General of Aquaculture Fisheries. Jakarta. p. 37 in Bahasa Indonesia.

Directorate General of Capture Fisheries 2002 Handbook of the Capture Fisheries Statistics of Indonesia 2002. Directorate General of Aquaculture Fisheries. Jakarta. p. 121.

Erdmann M.V. and Pet-Soede L. 1996 The live reef fish trade in eastern Indonesia NAGA, The ICLARM Quarterly. January 1996. pp. 4–8.

Johannes R.E. and Riepen M. 1995. Environmental, economic, social implications of the live reef fish trade in Asia and the Western Pacific. Report to the Nature Conservancy and the South Pacific Forum Fisheries Agency. 82 pp.

Kawahara S. and Ismi S. 2003 Grouper seed production statistics in Indonesia 1999–2002. Research Institute for Marine Aquaculture-Gondol in cooperation with Institute for the Lampung marine aquaculture development and the Situbondo brackish water aquaculture development, Department of Marine Affairs and Fisheries. Indonesia. 16 pp.

Lowe C. 2004 Who is blame? Logics responsible in the live reef food fish trade in Sulawesi, Indonesia. SPC Live Reef Fish Information Bulletin No. 10.

Manadiyanto, Zahri N., Purnomo A.H., Pranowo S.A. and Azizi dan Tajerin A. 2002. *Pengembangan Model Bisnis Senter Ikan Kerapu di Batam, Riau*. Pusat Riset Pengolahan Produk dan Sosial Ekonomi Kelautan dan Perikanan, BRKP — DKP. (Laporan teknis). Jakarta. 46 halaman. *Unpublished Technical Report*.

Mous P.J., Pet Jos S. and Djohani R. 2002 Grouper culture as a tool in Marine Park Management — A Project of the Nature Conservancy, Indonesia Coastal and Marine Program. In APEC/NACA (2002) 'Report of the APEC/NACA Cooperative Grouper Aquaculture Workshop, Hat Yai, Thailand, 7–9 April 1999'. Collaborative APEC Grouper Research and Development Network (FWG 01/99). NACA-Bangkok-Thailand. p. 151.

Pet J.S. and Pet-Soede L. 1999 A note on cyanide fishing in Indonesia. Live Reef Fish Information Bulletin 5, 21–22.

Rimmer M.A. 2002 Overview of Grouper Production Technology in the Asia–Pacific Region. In APEC/NACA (2002) 'Report of the APEC/NACA Cooperative Grouper Aquaculture Workshop, Hat Yai, Thailand, 7–9 April 1999'. Collaborative APEC Grouper Research and Development Network (FWG 01/99). NACA-Bangkok-Thailand. p. 151.

Sumaryono W. 2002 Rencana Induk Rusnas Kerapu. hal: 3-32. dalam Alia, R.S., Herdis, Afifah dan M. Surachman (Eds.). Menggalang Sinergi Untuk Mengembangkan Agribisnis Kerapu. Prosiding Lokakarya Nasional dan Pameran Pengembangan Agribisnis Kerapu II, Jakarta 8–9 Oktober 2002. Pusat Pengkajian dan Penerapan Teknologi Budidaya Pertanian, BPPT. Jakarta. 248 halaman. In Bahasa Indonesia.

Sunaryanto A., Sudjiharno and Chaidir I. 2002 pengembangan Teknologi Budidaya Ikan Kerapu di Indonesia. Hal: 34-48 *dalam* Alia, R.S., Herdis, Afifah dan M. Surachman (Eds). Menggalang Sinergi Untuk Mengembangkan Agribisnis Kerapu. Prosiding Lokakarya Nasional dan Pameran Pengembangan Agribisnis Kerapu II, Jakarta 8–9 Oktober 2002. Pusat Pengkajian dan Penerapan Teknologi Budidaya Pertanian, BPPT. Jakarta. 248 halaman.

10. A predictive dynamic model of Indonesian live reef fish for food

Akhmad Fauzi[1]

Introduction

Fishing for live reef fish has been an important source of income for millions of fishers in Indonesia. Live reef fish are not only a source of cheap protein for coastal communities: they also provide jobs and source of export earnings for Indonesia. The sedentary nature of many reef fish makes them easier to catch therefore this type of fishing is relatively cheaper than other types of fishing.

In the beginning, exploitation of reef fish was intended primarily to fulfil local consumption. However, with increasing demand for live reef fish for food (LRFF) in Asian restaurants, especially in Hong Kong, the exploitation of live reef fish has became a global concern (Lau and Parry-Jones, 1999, Petersen *et al.*, 2004). Indonesia has been one of the major exporting countries of live fish since 1993; and it is predicted that the country will continue to play a major role in supplying the product to the international market in the years to come. The international trade of reef fish from Indonesia is mostly concentrated on some species of groupers (Serranidae, especially *Cromileptes altivelis* and species of *Plectropomus* and *Epinephelus*) and Napoleon wrasse (*Cheilinus undulates*), with recorded prices ranging from US$2 to US$35 per kg. Some overseas customers are often willing to pay up to hundreds of dollars per kg (Mous *et al.*, 2000). With such a wide range in price, the Indonesian LRFF trade has been a lucrative business for Indonesian fishers with the result of increasing of fish production from Indonesian waters.

During the last decade, the production of Indonesian live reef fish, especially wild caught groupers, has shown a significant increase (Figure 1). In 1990, the production of wild caught groupers was estimated to be 16 000 metric tonnes. In the year 2000, production had increased to 48 500 metric tonnes which is a three-fold increase (Pet-Soede *et al.*, 2004). The major contributors of the capture of wild caught groupers are Sumatera (also known as Sumatra) (38%) and Sulawesi (22%). Even though there are no quantifiable data on the production of farmed groupers, there is a strong indication that production of these fish has also been increasing slightly (Pet-Soede *et al.*, 2004)

An increase in exploitation of LRFF, however, has a double-edged sword effect. While an increase in production of LRFF has brought export earnings and income for fishers up to a favourable level, rapid exploitation has also led to a serious effect on the environment. It is widely known that in Indonesia, fishers tend to use the quickest and the easiest methods to catch fish, which, in this case, is to use cyanide solution to stun the fish, resulting in severe reef degradation. A study by Mous *et al.* (2000) for example, showed that because of this fishing technique, there is potential loss of live coral cover ranging from 0.004 percentage point to 0.5 percentage point per year (Table 1).

There have been numerous attempts to reduce the pressure on LRFF by influencing market demand and by implementing other regulatory measures. However, there seems to ongoing high pressure on the grouper stocks due to continuing strong demand for this fish, coupled with weak regulatory enforcement (Graham, 2001). In addition, models dealing with LRFF are lacking, especially predictive models used for policy analysis. This paper attempts to bridge that gap and to provide

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information on how a dynamic model could be used for policy inputs (to handle the problems associated with LRFF). The paper begins with an assessment of sustainability of the LRFF trade in Indonesia, followed by a dynamic simulation of the interaction with the fish stock and its demand, as well as a prediction of demand and supply for LRFF and the implications on the resource.

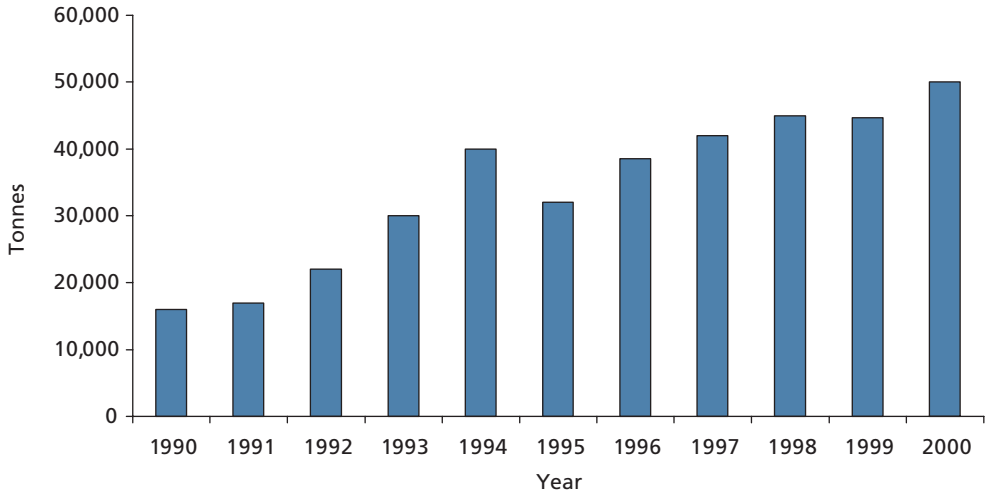

Figure 1. Production of wild-caught groupers in Indonesia (source: Pet-Soede *et al.*, 2004).

Table 1. Estimation of reef degradation in Indonesia caused by the LRFF trade. Source: Mous *et al.*, (2000).

Method/Variable	Best case	Conservative	Worst case
Area of live coral cover lost per cyanide bottle used or per fish caught (m²)	1	0.3	3
Method 1: Production and yield of groupers by large-scale operations in pristine environments:			
MSY (kg/km² coral reef. per year)	1000	500	2000
Body weight per fish (kg)	3.33	6.66	1.67
Reef degradation (% points loss year^{-1})	0.060	0.005	0.719
Method 2: Fishing effort and CPUE of medium-scale operations:			
Effort (trips day^{-1}, km^{-2} reef)	0.19	0.095	0.38
Fish caught per unit effort	7.5	3.75	15
Reef degradation (% points loss year^{-1})	0.052	0.004	0.624
Method III: Volume of LRFF, mostly caught by medium-scale operations:			
Hong Kong imports (tonnes)	32 000	25 600	38 400
Through Hong Kong (%)	60	80	40
From Indonesia (%)	50	70	30
Post-harvest mortality (%)	50	30	70
Body weight of fish (kg)	1.33	2.66	0.67
Reef degradation (% points loss year^{-1})	0.047	0.004	0.502

Sustainability assessment

One of the big issues associated with the LRFF trade is that the exploitation of the resource is not sustainable. Yet, the Fisheries and Agriculture Organisation (FAO) code of conduct (FAO, 1995) dictates that measures to achieve sustainability must be implemented by all fishing practices in all coastal nations in order to preserve their resource and economic livelihood in the long term. Sustainability, however, encompasses many aspects which include ecological, economic, social, technological and ethical dimensions. To assess the sustainability of the LRFF fishery, in contrast with the exploitation of other fisheries such as big and small pelagic fisheries, a sustainability

assessment technique was used based on *Rapfish* (Rapid Appraisal for Fisheries) which was developed by Alder *et al.* (2000). This assessment measures how good, on a sustainability index, fishing for live reef fish is based on the ecological, economics, social, technological and ethical dimensions of the fishery. Each of these dimensions has attributes or characteristics that could be used as indicators to measure the sustainability of the fishery. To employ the Rapfish technique, data from official fishery statistics, supported by some other reports and articles were used to score this fishery (Fauzi and Anna, 2002). The LRFF fishery is contrasted with another seven types of fisheries exploitation in the country which include big and small pelagics, shrimps, demersal species, molluscs, chepalopods, and crustaceans.

Figures 2 to 6 depict the ordination of sustainability of LRFF relative to other fisheries. The ordination describes the position of each fishery on a scale of zero to 100. Zero indicates a bad score of sustainability while 100 indicates a perfect score of sustainability.

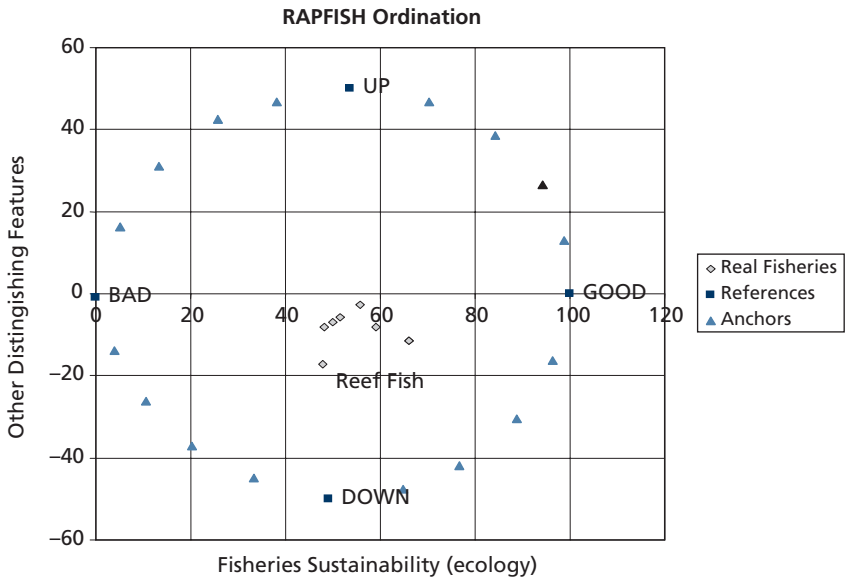

Figure 2. Ordination of the ecological dimension of fisheries in Indonesia.

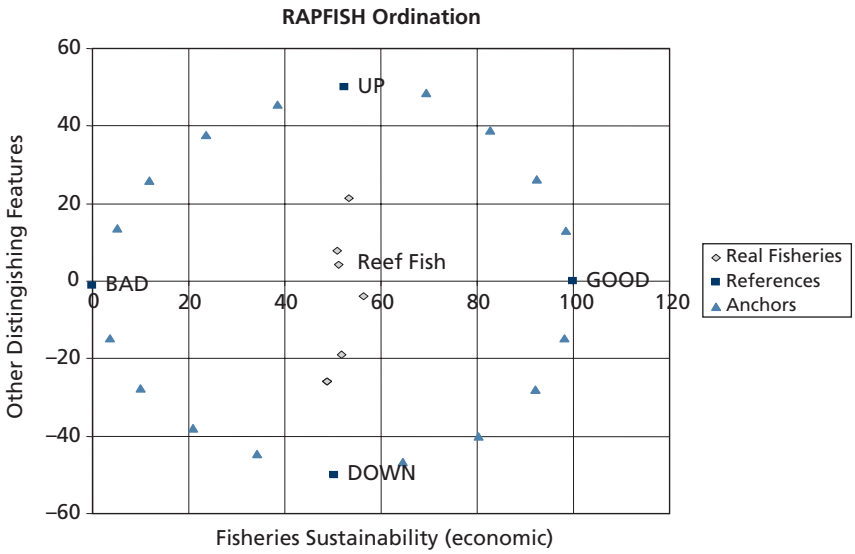

Figure 3. Ordination of the economic dimension of fisheries in Indonesia.

As can be seen from Figures 2 to 6, the LRFF fishery shows a low score of sustainability in almost all dimensions, except for the economic dimension. This also can be seen more clearly in Figure 7. This indicates that even though the industry is high value in terms of economic returns, the pressure of this fishery on the stock and environment would result in adverse impacts if nothing can be done to reverse the trend. These results also confirm qualitative assessments previously mentioned by many observers (Pet-Soede *et al.*, 1999; Pet-Soede *et al.* 2004) regarding the exploitation of LRFF in Indonesia.

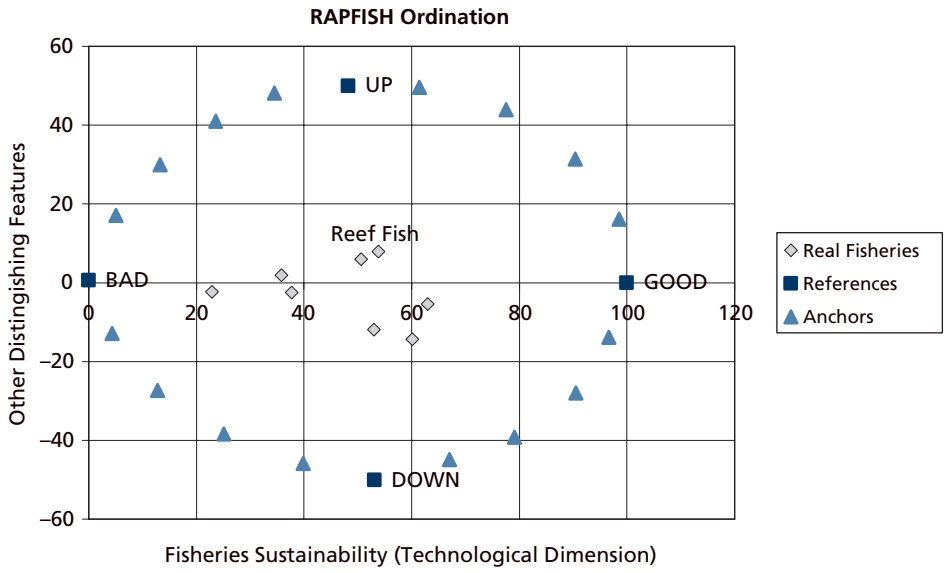

Figure 4. Ordination of the technological dimension of fisheries in Indonesia.

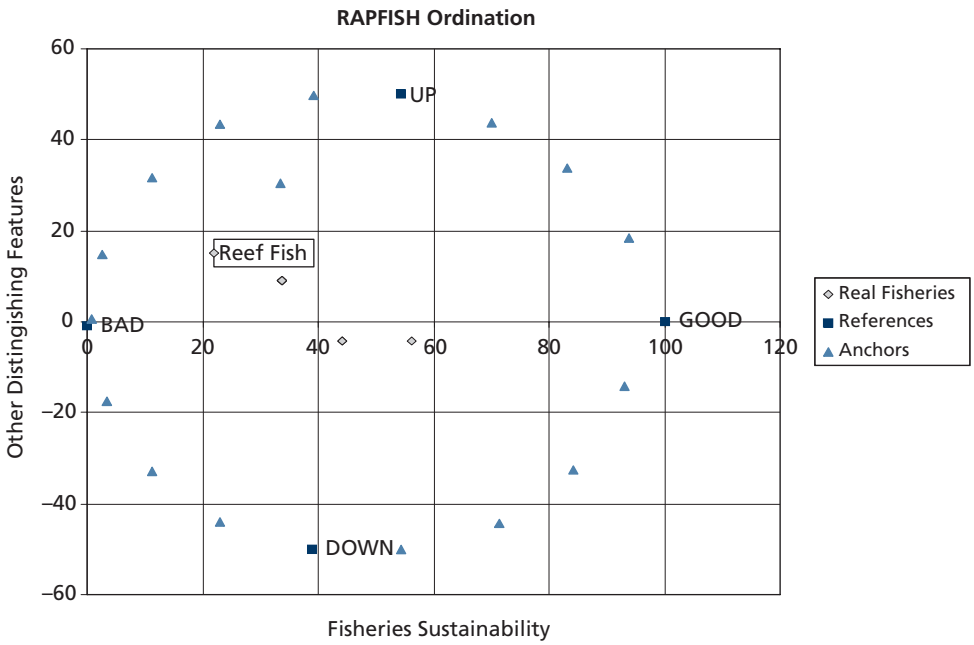

Figure 5. Ordination of the social dimension of fisheries in Indonesia.

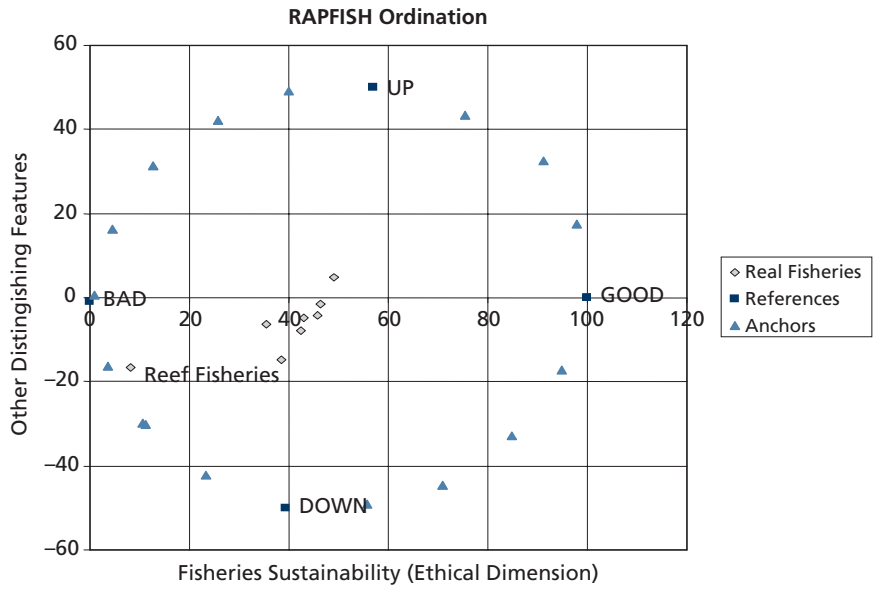

Figure 6. Ordination of the ethical dimension of fisheries in Indonesia.

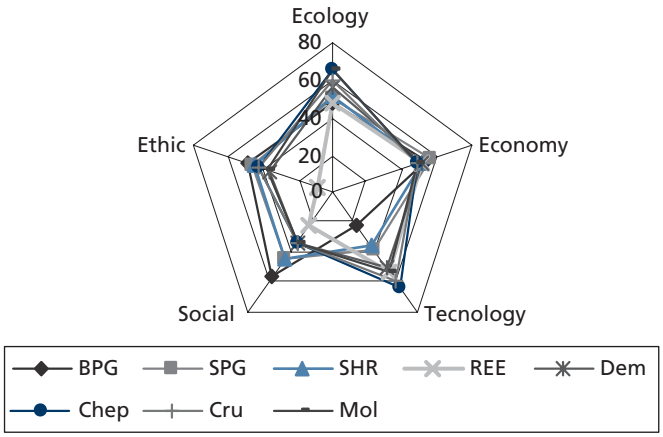

Figure 7. Radar diagram of sustainability of fisheries in Indonesia.

Dynamic simulation model

After estimating the sustainability of the LRFF fishery, the next question is: 'How would this fishery behave in the long run when market forces continue to play a role?' To answer this question, a dynamic simulation model was employed. The model consists of two parts. The first part is the baseline model deals with a constant price. The second part deals with a dynamic price path in which the price of LRFF received by the industry follows a dynamic process due to the forces of the demand side.

The baseline model is basically an extension of a standard dynamic model of Wilen's open access dynamics (Wilen, 1969). The parameter used for the simulation was calculated using a 'back of the envelope' technique by transforming some parameters previously estimated by other authors. For example, to calculate the carrying capacity (denoted by K) of the groupers, the following formula was used in the model:

$$h_{msy} = \frac{rK}{4} \tag{1.1}$$

where h_{msy} is production at the maximum sustainable yield, and r is the intrinsic growth rate. Mous *et al.* (2000) estimated that the Maximum Sustainable Yield (MSY) of groupers is 1000 kg per km^2, while Anna (2003) estimated that the intrinsic growth rate for the same species was 0.362 ton per year. Using these two parameters, one can estimate the carrying capacity required to run the simulation.

The dynamic of the LRFF fishery follows the following system of difference equations:

$$x_{t+1} - x_t = rx_t(1 - \frac{x_t}{K}) - qx_tE_t \qquad (1.2)$$
$$E_{t+1} - E_t = \sigma(pqx_t - c)E_t$$

where x_t is the stock of fish at period t, E_t is the level of effort exerted to the fishery (per trip) and q is the catchability coefficient. Parameters p and c represent price and cost respectively. A complete list of parameters used in the simulation is listed in Table 2.

Table 2. Parameters used in the dynamic simulation model.

Parameter	Values	Source
K (carrying capacity)	1000	Own calculation
r (growth rate)	0.362	Anna (2003)
q (catchability coefficient)	0.0168	Anna (2003)
p (price)	US $10 kg	Pet-Soede *et al.* (2004)
c (cost per unit of effort)	US $3.2. per trip	Pet-Soede *et al.* (1999)
σ (adjustment factor)	0.3–0.8	Fauzi and Anna (2004)
i (discount rate)	8%	Own calculation

The dynamic simulation model was implemented using Ventana Simulation software and is described in the iconic model shown in Figure 8.

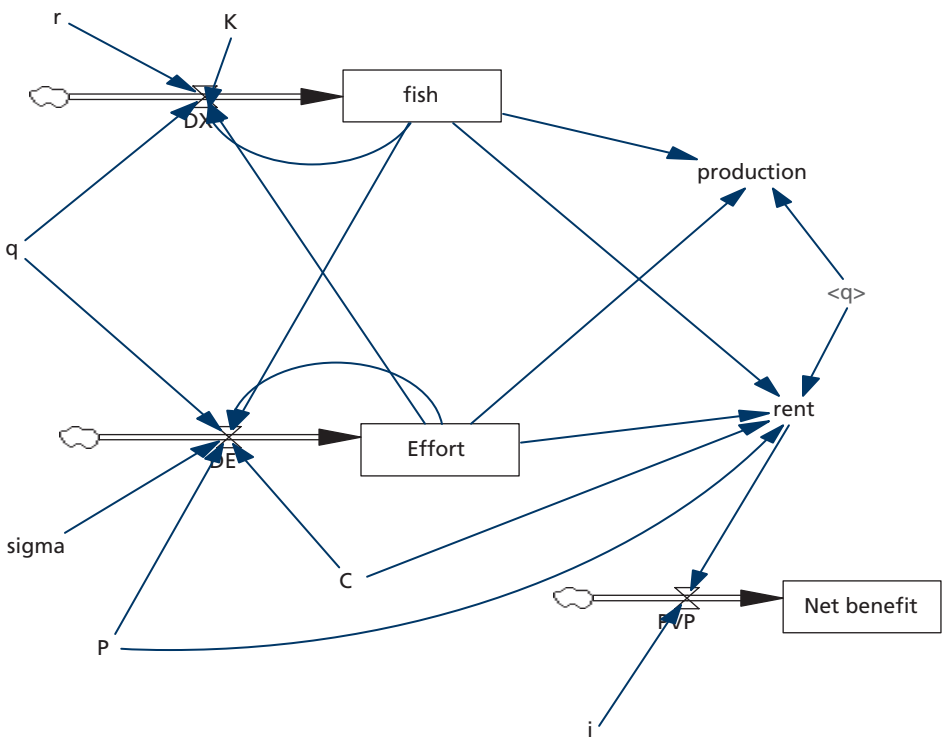

Figure 8. Iconic model of dynamic simulation.

Results from the simulation with various adjustment coefficients are described in Figure 9 through Figure 12. In general, two patterns of long run trajectories emerged. That is, if the adjustment coefficient was greater than 0.5, meaning that input to the fishery is very much reactive to the profits or economic rents generated from the LRFF fishery, the trajectories of effort and production head toward disequilibrium. In dynamic terms, this behaviour is called 'exploding oscillation'. Under this scenario, the yield of LRFF per km^2 would reach 600 kg per km^2 as predicted by Mous *et al.* (2000), while the amount of effort (number of trips) would go to 10 trips per year. Pet-Soede *et al.* (1999) estimated that the average number of trips for LRFF vary from 2.5 to 20 trips per year. Therefore, the predictive model indicates that, in the long run, the level of effort would oscillate around 10 trips per year.

When it is assumed that effort is less responsive to the level of profits, the trajectory of production and effort would be called a 'dumped oscillation', indicating that the equilibrium would converge to zero in about 10 years. That is, if somehow, the price of groupers is no longer attractive, then exploitation would cease and the destruction of coral reef would halt. This is a 'pure conservation scenario' which is unlikely to happen in Indonesia.

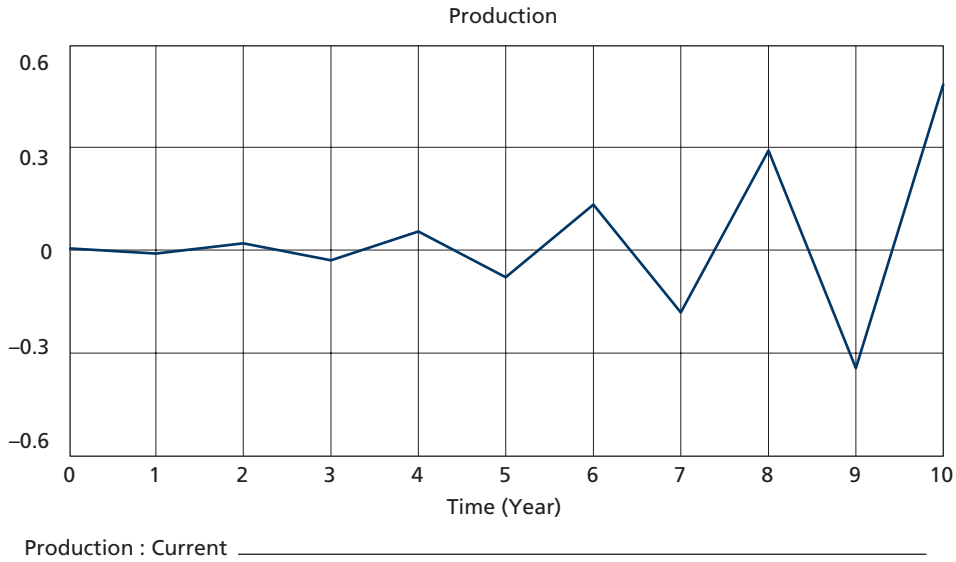

Figure 9. Trajectory of production for sigma = 0.7.

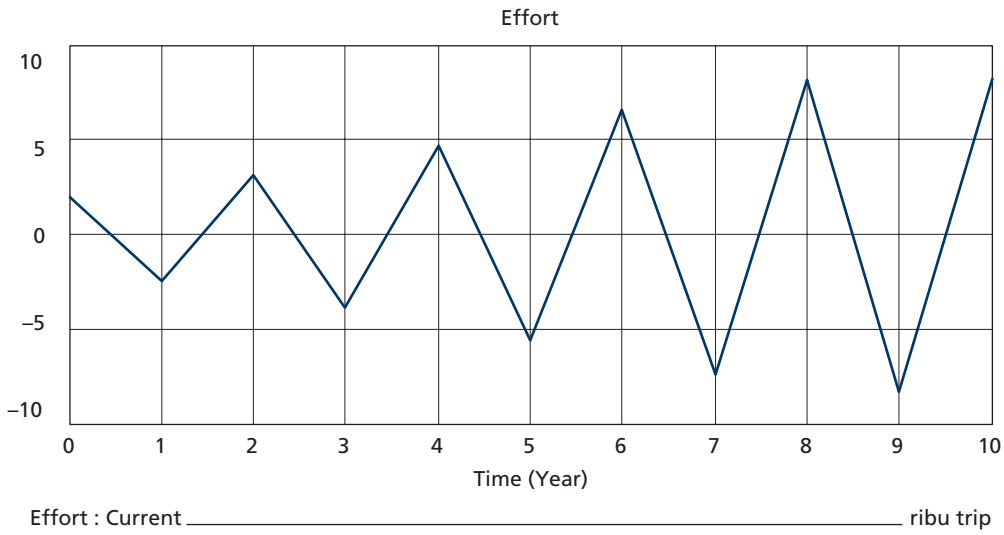

Figure 10. Trajectory of effort for sigma = 0.7.

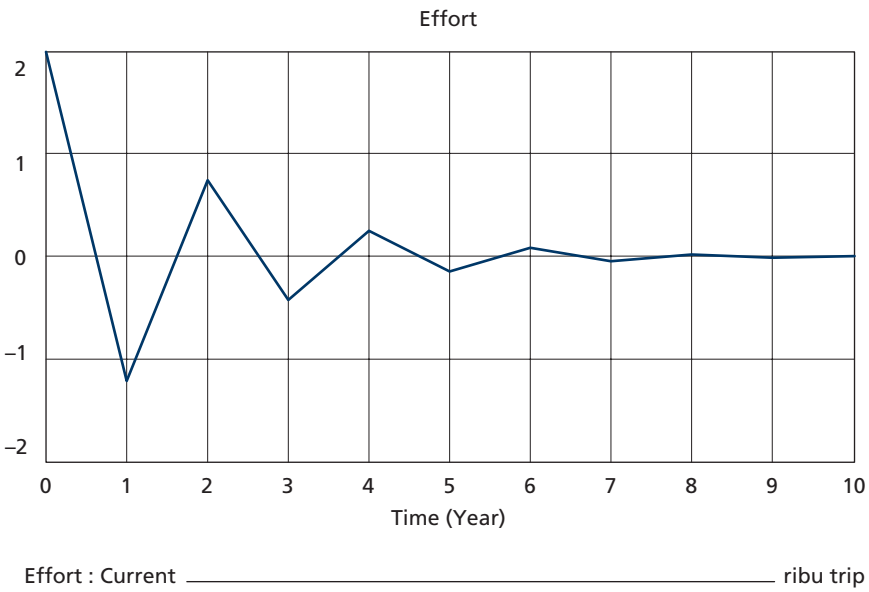

Figure 11. Trajectory of effort for sigma = 0.5.

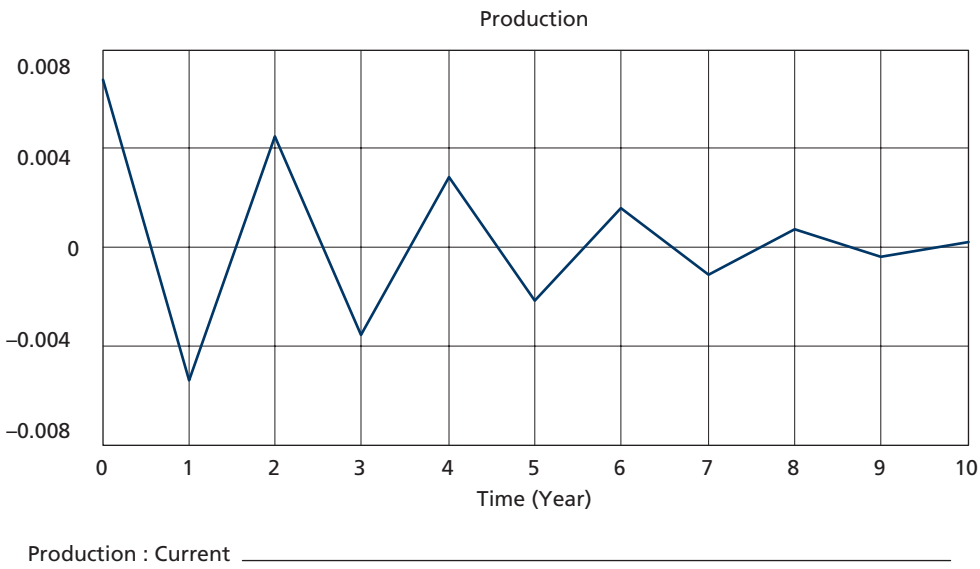

Figure 12. Trajectory of production for sigma = 0.5.

In the following section, the baseline model is extended to accommodate the dynamics of demand side for LRFF. To do this, the assumption of the constant price is relaxed and the price path of LRFF is assumed to follow the difference equation which is referred as a non-monotonic demand curve. Such a demand curve is usually produced by the Cobweb Model (Clark, 1990) using the following equations for supply and demand:

$$Q(t) = S(P_{t-1}) = A + BP_{t-1} - CP^2_{t-1} \qquad (1.3)$$
$$Q(t) = D(P_{t-1}) = D - \phi P_t$$

Where A, B, C, D and ϕ are constant parameters, representing intercepts and slopes of demand and supply curves. Under market clearing conditions, equation converges to the following equation

$$P_t = \alpha - \beta^P{}_{t-1} + \gamma P^2{}_{t-1} \qquad (1.4)$$

To simplify notations, let $\alpha = (C - A)/D$, $\beta = B/D$ and $\gamma = \phi/D$. The complete model, therefore has three difference equations i.e., one from equation and two from equation. Furthermore, the dynamic of effort from equation (1.2) can be written as:

$$E_{t+1} - E_t = \sigma[(\alpha - \beta P_{t-1} + \lambda P^2_{t-1})qx_t - c]E_t \qquad (1.5)$$

The model was implemented using the 'Berkeley Madonna solver' (Macey and Oster, 2000) and described by the iconic model shown in Figure 13.

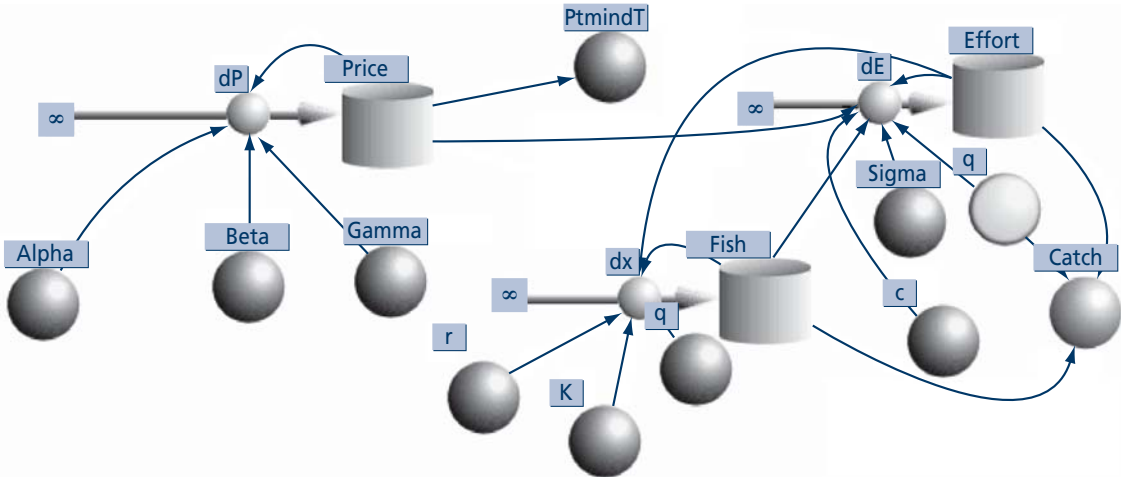

Figure 13. Iconic representation of the Cobweb Model.

Results of the extension version of the baseline model are the following. Figure 14 shows the behaviour of the price path in the long run, while Figure 15 descries the interaction of the price path and the supply of fish. It shows that while the equilibrium price would converge to US$3 per kilogram, the market forces will effectively change the long run equilibrium price to around US$30 per kg (as indicated by the red line). As a result, the supply of fish will react accordingly by reaching more than 700 kg per km^2. If this scenario continues to occur, then the environmental consequences must be taken into account. Under a moderate scenario of exploitation, the rate of reef degradation would be around 0.047% to 0.06% point loss per year; this rate would eventually increase by more than 15% from the current level.

The interaction of these forces will eventually affect the behaviour of input (effort) devoted to LRFF which will have consequences for the stock of fish in the long run. This can be represented using a phase-plane diagram as shown in Figure 16.

As can be seen from Figure 16, the long run behaviour of effort and stock of LRFF would result in a stable centre. That is, in the long run, the level of effort would settle at around 18 trips per year while the number of biomass stock would settle at 18 000 kg per km^2. This equilibrium suggest that to achieve a higher level of biomass stock current levels of effort must be reduced even though the forces of demand (price path) is increasing.

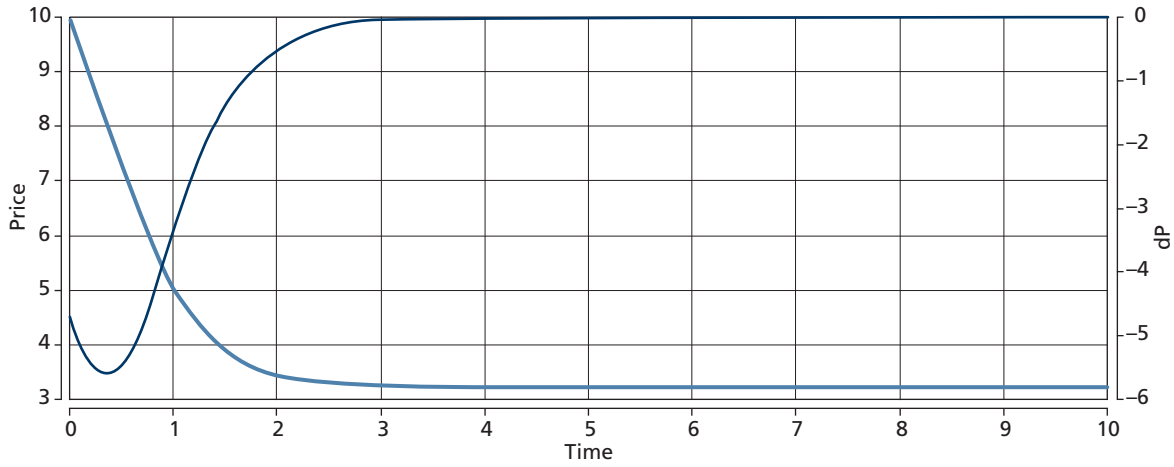

Figure 14. Behaviour of price along the dynamic path.

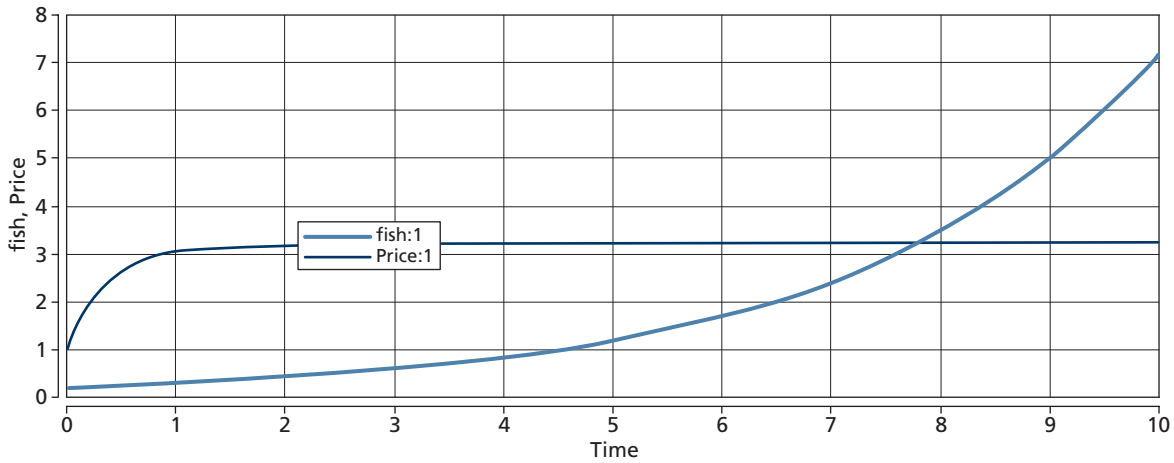

Figure 15. The interaction of the price path and the supply of fish under the Cobweb model.

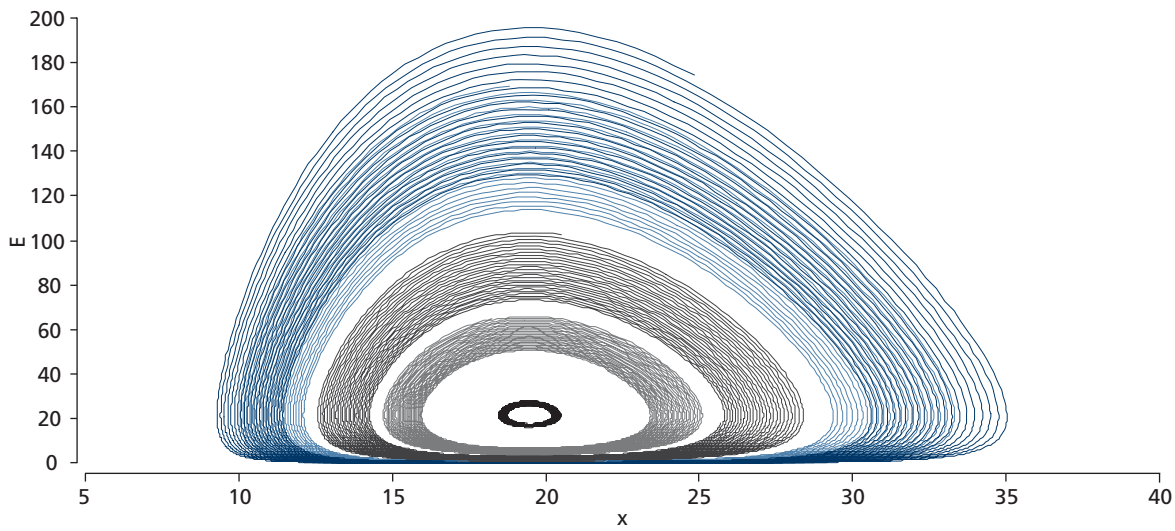

Figure 16. Phase-plane of stock and effort under the Cobweb Model.

Concluding remarks and direction for further research

The model described in this paper is only a preliminary model to investigate the problem of managing the of LRFF trade in Indonesia. This simple model could be applied to capture fundamental economics problem of LRFF exploitation in developing countries and its consequence to the sustainability of the resource and its environmental impact. The model is also able to accommodate the behaviour of some economic and biophysical variables which play a role in the management of the LRFF trade.

An in-depth analysis, however, is needed to integrate this simple model into a more general model of for the LRFF trade. Similarly, the exact dynamic price adjustment must be estimated more broadly to include a wide coverage area in the country, as well as the influence of other deterministic variables of the demand and supply function. Further bio-economic modelling is also needed to capture other behaviour of LRFF such as the dynamic of social and institutional forces; as well as to study the optimal level of control instruments in terms of input and output of the fishery.

References

Alder J., Pitcher T.J., Preikshot D., Kaschner K. and Feriss B. 2000. How good is good? A rapid appraisal technique foran evaluation of the sustainability status of fisheries of the North Atlantic. In: Pauly and Pitcher (eds). Methods for evaluating the impacts of fisheries on the North Atlantic ecosystem. Fisheries Center Research Reports, 2000 Vol (8) No. 2.

Anna S. 2003. Model embedded dinamik ekonomi interaksi perikanan-pencemaran (A dynamic embedded model of fishery-pollution interaction). Dissertation. Graduate Program in Coastal Management. Bogor Agricultural University (IPB).

Clark, C.W. 1990. Mathematical Bioeconomics. The Optimal Management of Renewable Resources. 2nd edition. John Wiley & Son, Inc. New York. USA.

FAO. 1995. Code of Conduct for Responsible Fisheries. Food and Agricultural Organization. Rome

Fauzi A. and Anna S. 2002. Evaluasi Status Keberlanjutan Pembangunan Perikanan: Aplikasi Pendekatan Rapfish (*An evaluation of Sustainability status for fisheries: An Application of Rapfish Method*). Journal of Indonesian marine and costal Vol 4 (2) pp 36-49.

Fauzi A. and Anna S. 2004. Analisis deplesi dan degradasi sumber daya pesisir dan laut (*Analysis of depletion and degradtion of coastal and marine resources*). Paper presented at National Meeting of Survey and Mapping of Natural Resources. Pontianak October 13, 2004.

Graham T.R. 2001. A collaborative strategy to address the live reef food fish trade. Asia Pacific Coastal Marine Program. Report # 0101. The Nature Conservancy, Honolulu, HI, USA.

Lau P.P.F and Parry-Jones R. 1999. The Hong Kong trade in live reef fish for food. Traffic East Asia and World Wide Fund for Nature Hong Kong. Hong Kong.

Macey R. and Oster G. 2000. Berkeley Madonna Version 8.0.1. Kagi Shareware, Berkeley, CA. USA

Mous P.J., Pet-Soede L., Erdman M., Cesar H.S.J., Sadovy Y. and Pet J.S. 2000. Cyanide Fishing on Indonesian coral reef for the live food fish market — What is the problem. SPC Live Reef Fish Information Bulletin No. 7 — May 2000.

Pet-Soede C., Cesar H.S.J. and Pet J.S. 1999. An economic analysis of blast fishing on Indonesian coral reefs. Journal. Environment Conservation, 26 (2): 83–93. Foundation for Environment Conservation.

Pet-Soede L., Horuodono H. and Sudarsono. 2004. SARS and the live food fish trade in Indonesia: Some anecdotes. SPC Live Reef Fish Information Bulletin No. 12. Australia.

Petersen E., Muldoon G. and Johnston B. 2004. Economic Modelling of the live reef fish trade in Asia–Pacific: Developing an approach and preliminary analysis. Paper contributed to the 48th Annual Conference of The Australian Agricultural and Resource Economics Society, 11–13 February 2004. Melbourne.

Wilen J.E. 1969. Common property resource and the dynamics of overexploitation: The case of the North Pacific fur seal. Department of Economics Research Paper No. 3 University of British Columbia, Vancouver. Canada.

11. Finding Nemo: estimating import demand for live reef food fish

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Abstract

Reef fish traded alive for table food are high value-to-volume products, with demand centred in Hong Kong and southern mainland China. Import demand functions for live reef food fish are estimated for Hong Kong, in aggregate and for individual fish species. Cross-price, income and population elasticities, and the impact of Severe Acute Respiratory Syndrome and Chinese New Year on demand, are estimated. Results show that price has a smaller influence on import demand than expected. The most influential factor is Chinese New Year. The price of low and medium-value species exhibited a negative impact, whereas the price of very high-value species exhibited a positive impact, on demand. This suggests that high-value live reef species may be Veblen goods, where consumption increases as a direct function of its price, in this case due to associated prestige and status.

Introduction

Live fish have long been traded throughout Southeast Asia as a luxury food item. Species captured on coral reefs entered this trade in the 1970s and, because of their superior qualities (such as taste, colour and texture), have become some of the most sought after species. Sadovy and Vincent (2002) estimate that 60 per cent of the international trade goes to Hong Kong, with as much as 50 per cent of this being re-exported to southern mainland China where direct import tariffs are currently significantly higher than in Hong Kong (this is likely to change with China's accession into the World Trade Organisation). Hong Kong imports approximately 15–20 000 tonnes annually, valued at approximately US$350 million (Muldoon and McGilvray 2004). Given this, the global trade in live reef fish may exceed 30 000 tonnes annually. In the immediate wake of the Asian economic crisis, declared imports of live fish into Hong Kong declined by almost one-third and have since failed to recover from these levels (Muldoon and McGilvray 2004).

While fish consumption has been a staple dietary component of these countries for centuries, live reef fish are consumed in especially high quantities during special occasions and festivals (for example, in celebration of Chinese New Year, Mother's Day and to mark the close of business agreements). These festive periods often correspond with higher prices paid to fishers in source countries. Approximately twenty Asia–Pacific countries supply these markets, with Thailand, the Philippines, Australia, Malaysia and Indonesia being the dominant suppliers (ACFD 2003). In this paper, we refer only to live reef fish traded for table food and not aquarium display, which was estimated in the late 1990s to range between US$90 and US$400 million (Sadovy and Vincent 2002).

A number of economic, environmental and social issues have arisen as a result of the trade. Preliminary data analysis indicates that the live reef fish trade has been susceptible to economic shocks such as the Asian Economic Crisis and Severe Acute Respiratory Syndrome (SARS),

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a severe form of pneumonia (Muldoon and McGilvray 2004). The impacts of these shocks are felt throughout the supply chain, from the fisher to the retailer, to differing degrees. There are concerns about the sustainability of supply due to economic and biological over-exploitation of coral reefs and the environmentally damaging aspects of some harvesting techniques; including cyanide fishing and targeting of spawning aggregations (Cesar *et al.*, 2000). Moreover, the trade is beset by social disruption, which arises mainly due to disputes over resource access and use, distribution of benefits, and the use of destructive fishing practices (see Smith, 2004). In many cases, while the trade has provided additional income generating opportunities, these benefits have come at a cost to future ecological, economic and social sustainability.

Quantities of live fish traded regionally are difficult to determine. Actual records of annual imports of live fish into Hong Kong are derived from data collected by the Census and Statistics Department, and the Agriculture, Fisheries and Conservation Department (AFCD). The reliability of these estimates is hindered by the re-export of live fish into southern mainland China and the likely under-recording of imports. This latter issue is largely a result of there being no requirement for Hong Kong registered live transport vessels to declare their imports. The AFCD estimates of live marine fish entering Hong Kong by sea are thought to capture only about 50 per cent of all shipments although the data do not distinguish country of origin.

The market for live reef fish includes a wide variety of low-value (e.g. mangrove snapper, green grouper and flowery grouper), medium-value (e.g. tiger grouper, giant grouper, spotted coral trout and leopard coral trout) and high-value fish species (e.g. humphead wrasse and humpback grouper) (Table 1).

The preferred family of fish species are the grouper (Serranidae). The humphead (Napoleon) wrasse remains one of the highest priced, most sought after and most endangered species in the trade.The leopard coral trout is especially favoured due to its bright red colour. The preferred size of fish for consumption is 600–1000 grams. Leopard coral trout is on the upper end of the medium-priced continuum and during peak demand periods exhibits high-value status. It is considered a high value species in most exporting countries.

A campaign conducted in June 2004 to raise public awareness of the endangered species humphead wrasse led to an online petition of more than 3000 signatures urging the Hong Kong government to save the species. These signatures were submitted to the representative of the Hong Kong AFCD ahead of voting in October for the listing of the fish on the Convention of International Trade on Endangered Species of Fauna and Flora (CITES) Appendix II.

This paper, funded by the Australian Centre for International Agricultural Research (ACIAR), is the first analysis of a larger project aimed at analysing economic and market impacts of the live reef food fish trade in Asia–Pacific. The aim is to provide single equation estimates of import demand for live reef food fish in Hong Kong, analysing the effects of population growth, seasonal factors (i.e. Chinese New Year), income growth and economic shocks (i.e. SARS). The analysis provides initial exploration of data before demand systems are estimated. The paper is structured as follows. Section 2 is a discussion of the theory of demand for fish with preliminary analysis for live reef fish to develop hypotheses regarding own-price (Section 2.1), cross-price (Section 2.2) and income elasticities (Section 2.3). Section 3 provides the results and discussion of demand analysis, conducted in three stages: aggregated demand analysis (Section 3.1), demand analysis disaggregated by low, medium and high-valued species (Section 3.2), and demand analysis for individual species (Section 3.3). Some conclusions are drawn in Section 4.

Table 1. Average landed price, quantity and value of live reef fish species imported annually into Hong Kong (2001–2003), excluding Hong Kong-flagged shipping vessels[1].

Variable	Average price (HKD/kg)	Average annual quantity imported (tonnes)	Value (million HKD)
Low-value species			
'Other marine fish'	23.5	4 360	102
Mangrove snapper	40.6	255	10.4
Green grouper	57.8	1 470	84.9
Flowery grouper	75.6	132	10.0
Medium-value species			
'Other groupers'	94.6	1 620	153
Tiger grouper	96.8	145	14.0
Giant grouper	100	10.0	1.00
Spotted coral trout	141	96.9	14.2
Leopard coral trout	147	2 140	314
High-value species			
Humphead wrasse	232	18.6	4.32
Humpback grouper	285	8.7	2.08
Total		**10 300**	**710**

Source: Hong Kong Trade Statistics from Census and Statistics Department.

[1] Hong Kong-flagged vessels are estimated to capture approximately 50 per cent of imports by sea to Hong Kong, averaging at approximately 1800 tonnes per year.

Demand theory and its application to live reef fish

Theory suggests that demand for a good depends on price, the average income of consumers, the size of the market (often measured by population), the price of substitutes, tastes/preferences, and special influences (such as festival occasions) (Sloman and Norris, 2002). To the authors' knowledge, no study has attempted to estimate demand for live reef fish. Wing and On (2002) is the only empirical study on the fishery known to the authors. They provide a time-series analysis of historical prices of three species of cultured groupers in Hong Kong using an Autoregressive Integrated Moving Average (ARIMA), but do not address structural changes in the industry. However, Wing and On (2002) were able to successfully predict future prices of two fo the three species analysed. Their model was not extended to estimate the demand functions for these fish species.

There are four different representations of the consumer's preferences that are dual in the sense that they provide identical information about the consumer's preferences: the utility function, the indirect utility function, the cost (or expenditure) function and the distance function. When using a *utility function* it is assumed that the consumer's preferences may be represented with a utility function $U(q)$, where q denotes a vector containing the quantity consumed of each good. Given a budget X, the consumer's problem is to maximise $U(q)$ given X. Deriving and solving the first order conditions to this problem yields a system of demand functions (known as the uncompensated or Marshallian demand functions), where the quantity demanded for each good is a function of prices and expenditure.

The first empirical demand studies specified single equation demand functions linear in the parameters, of which the double log was the most common functional specification (e.g. DeVoretz (1982), Kabir and Ridler (1984), Bird (1986), Hermann and Lin (1988), DeVoretz and Salvanes (1993), Hermann *et al.* (1993)). This specification is still common today, however, single equation models are generally not theoretically consistent as changes in the price of goods omitted from the specification may cause changes in demand for the commodity in question through changes in expenditure.

To estimate functions that are consistent with consumer theory, a system of demand functions is estimated using the concept of weak separability to separate a group of goods from the rest of the consumer's bundle. Weak separability assumes that the consumer partitions total consumption into groups of goods, so that preferences within groups can be described independently of the other groups. The demand functions for the goods inside the group are then specified in a system of demand functions. There are a number of demand systems specified in the literature, of which the most commonly used is the Almost Ideal Demand System (AIDS) of Deaton and Muellbauer (1980).

The purpose of this paper is to conduct an initial exploration of data by estimating a single import demand function for live reef fish. It is a precursor to system modeling of the fishery. A standard Marshallian demand function is used, expressing the quantity of a species demanded as a function of prices, income, seasonal factors and economic shocks:

$$q_i = f(p_i, p_s, p_c, y, s, e) \qquad (1)$$

where q_i is the quantity of species (or species group) i demanded in the period; p_i is the real price of species (or species group) i, p_s is a vector of the real prices of substitute products; p_c is a vector of the prices of complementary products(however not all species or species groups have complements or substitutes); y is the income of consumers (real gross domestic product (GDP) per capita), s is a seasonal dummy variable (indicating the occurrence of Chinese New Year); and e is a dummy variable indicating an economic shock (the incidence of SARS). Monthly data is used over the period from July 2000 to May 2004, provided by the AFCD of Hong Kong. The following subsections review the literature and propose hypotheses regarding own-price, cross-price and income elasticities of demand for live reef fish that can be derived from empirical analysis.

Price elasticity of demand

A number of general trends may be elicited from existing demand models for fish, although comparisons must be made with caution as model specifications used differ across studies. First, demand in most markets for seafood seems to be price elastic (Asche and Bjorndal, 1999). There are a few exceptions; for example, demand for some canned seafood in aggregate such as canned tuna (e.g. Wallstrom and Wessells (1995)). Second, there is a tendency for more valuable seafood to be exhibit more elastic demand. Third, existing demand analysis of fisheries show a tendency for demand closer to the consumer (e.g. retail demand) to be more elastic than demand closer to the producer (e.g. ex-vessel demand). This may be reflecting the short-run inelastic nature of the supply elasticities, where the supply of fish cannot change significantly with price due to stock catchability (in the case of wild capture) or farming (in the case of mariculture) constraints. A fourth, and related, finding from existing demand analysis is that price elasticities decrease with increases in supply, as one would expect with a movement down the demand curve.

As some live reef fish are high value-to-volume species, demand for these fish is also expected to be price elastic. Furthermore, the relatively high-priced live reef fish species are expected to have greater elasticities than the relatively low-priced species. For live reef species where production is increasing rapidly (e.g. leopard coral trout), the price elasticity of demand is hypothesised to be decreasing.

We identify two special demand features of the live reef fish trade. First, increases in demand during celebration periods (e.g. Chinese New Year and Mother's Day) leads to price spikes, suggesting consumers are willing to pay a considerable premium to ensure purchases during such periods. The price elasticity of demand may be highly inelastic during such periods. The second is consumers' willingness to pay higher prices for scarce fish species (e.g. humphead wrasse). It is also likely that the demand elasticities of these goods are positively related to income. The effect of these 'prestige' prices is likely to encourage greater levels of effort, leading to over-fishing of the resource in the absence of regulation.

Cross-price elasticities of demand

Demand studies of other fisheries provide some evidence that similar species and product forms tend to be the closest substitutes. Salvanes and DeVoretz (1997) found that the degree of substitution between seafood and meat is substantially less than between seafood products. Asche *et al.* (2001) and Jaffry *et al.* (2000) found little substitution between farmed and wild-caught products when comparing different species, but Asche *et al.* (2001) found some substitution when comparing similar species. It is expected that individual live reef fish species will be substitutes, especially species of similar value, and this substitutability is likely to be affected by seasonality.

Income elasticities of demand

Theory suggests that income elasticities of demand depend on the period over which they are measured (the shorter the time, the lower the income elasticity of demand) and the degree of necessity of the good (the more necessary the good, the lower the income elasticity of demand) (Sloman and Norris, 2002). Certain live reef fish species are considered luxury goods, consumed in especially high quantities during traditional Chinese festivals and to celebrate special occasions. It follows that income elasticities of demand may be quite high, more so for the relatively higher-valued species.

The Hong Kong economy has grown very slowly over the last few years due to a slowdown in the global economy, the Asian economic crisis and the economic effects of SARS (EIU, 2003). This slow economic growth has led to poor levels of growth in income, and hence disposable income that may be spent on reef fish consumption. The prospect for growth in the Hong Kong economy is promising for the medium term. Moreover, mainland China's economy has been growing strongly over the last few years and this looks to continue in the medium term. This income growth in Hong Kong, and especially mainland China, is likely to lead to increased demand for all species of live reef fish.

Results and discussion

Import demand analysis for live reef fish in Hong Kong is performed in three stages. First, demand for live reef fish species is estimated in aggregate (Section 3.1). Second, live reef species are divided into three categories: low-, medium- and high-valued species. Separate demand functions are

estimated for each of these categories (Section 3.2). Third, individual demand functions will be estimated for each species (Section 3.3). The data for each of the variables used in the analyses are presented below. These variables include quantity of live reef fish imported (aggregated), import price, income, population, and dummy variables indicating the occurrence of Chinese New Year and SARS.

Monthly imports of live reef fish into Hong Kong are derived from data collected by the Hong Kong Census and Statistics Department and the AFCD. There is compulsory reporting of all live reef fish imports, except those arriving by sea in Hong Kong-flagged vessels. These vessels voluntarily report imports. The AFCD estimates that these voluntary reports capture approximately 50 per cent of all shipments.

Monthly quantities of live reef fish imported into Hong Kong from July 2000 to May 2004 are shown in Figure 1. The thin line represents total imports into Hong Kong not including the voluntary reporting of Hong Kong-flagged ships. The middle line represents total imports including the voluntary reporting of Hong Kong-flagged ships. The top (most heavily bolded) line represents total imports with Hong Kong-flagged vessels multiplied by two to represent the AFCD's estimates that these vessels capture approximately 50 per cent of all shipments. Note that the data including Hong Kong-flagged vessels closely mirrors the peaks and troughs of data excluding these vessels. Voluntary reports from Hong Kong-flagged vessels report monthly imports of approximately 400 tonnes to early 2001, and declined after this to approximately 200 tonnes per month from early 2001 to May 2004. The reason for this break in the data is unclear but may be due to a data weakness. For this reason, and given the data in each curve mirror the same peaks and troughs, imports excluding Hong Kong-flagged shipments by sea are used in the demand analysis. However, the results should be considered in light of this.

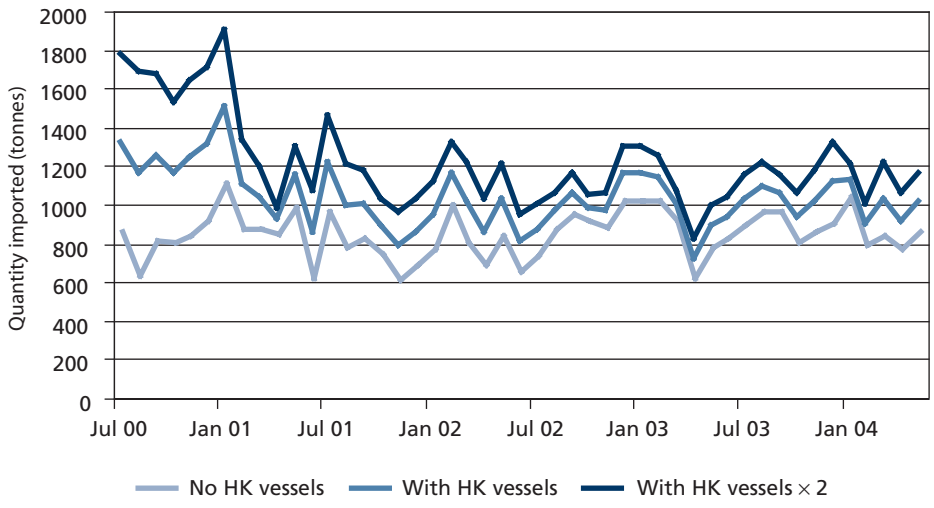

Figure 1. Monthly quantity of live reef fish imported into Hong Kong, July 2000 to May 2004.

The data excluding Hong Kong-flagged shipments by sea (the lowest line in Figure 1) do not appear to be 'trending' upwards or downwards. However, they do provide evidence of peaks during Chinese New Year (January 2001, February 2002, February 2003 (to a lesser extent), and January 2004). The quantity demanded spiked downwards in February to June 2003 during the SARS epidemic.

Figure 2 shows the weighted average price of live reef fish, imported into Hong Kong from July 2000 to May 2004. Price appears to be trending upwards until January 2002, after which it has been trending downwards. Price dropped dramatically during the SARS epidemic, but recovered strongly in August 2003. There does not appear to be obvious spikes in price during Chinese New Year (although spikes may be evident with individual species during this festival).

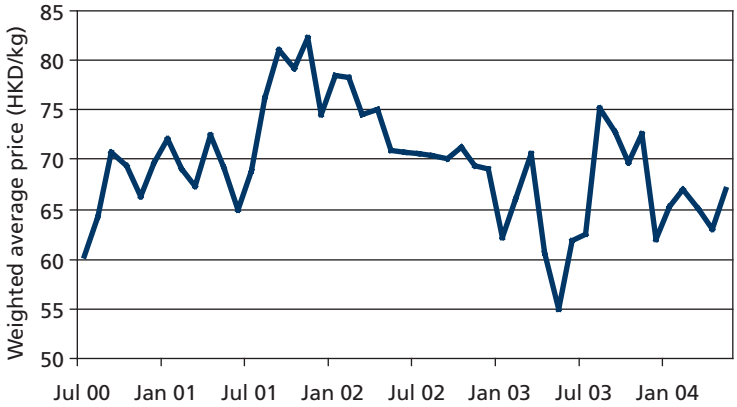

Figure 2. Weighted average price of live reef fish in aggregate, July 2000 to May 2004.

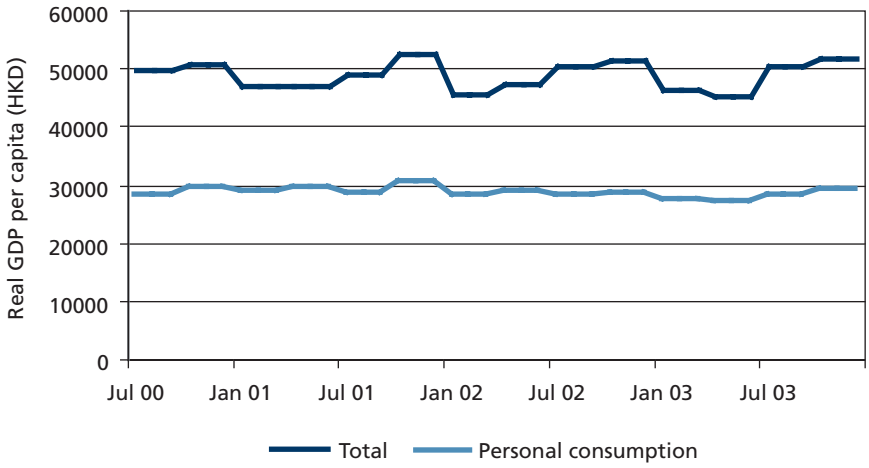

Figure 3. Real GDP per capita over time, total and personal consumption only.

Income is measured through real GDP per capita. Figure 3 displays real GDP per capita data in Hong Kong from July 2000 to December 2003. As noted in the previous section, GDP per capita growth was very slow during these years due to a slowdown in the global economy, the Asian economic crisis and the economic effects of SARS (this latter effect is evidenced in the decrease in total GDP per capita from January to July 2003). Given this slow growth, it is unlikely that any significant income-related trends can be drawn from the live reef fish trade data. It is expected that income will grow more strongly in the next few years. This may allow income-related trends in import demand to be estimated in more detail in the future.

Hong Kong's population grew steadily by just over 1 per cent per year from July 2000 to December 2003, totaling just over 6.8 million at the end of this period (Figure 4). The main lunar festival that is likely to affect live reef fish demand is Chinese New Year. This festival is included in the model as a dummy variable. Table 2 shows the dates when Chinese New Year occurred from 2000 to 2004. Preliminary analysis showed that other festivals, such as Mothers Day, did not significantly affect import demand for any live reef fish species and was omitted from the analysis.

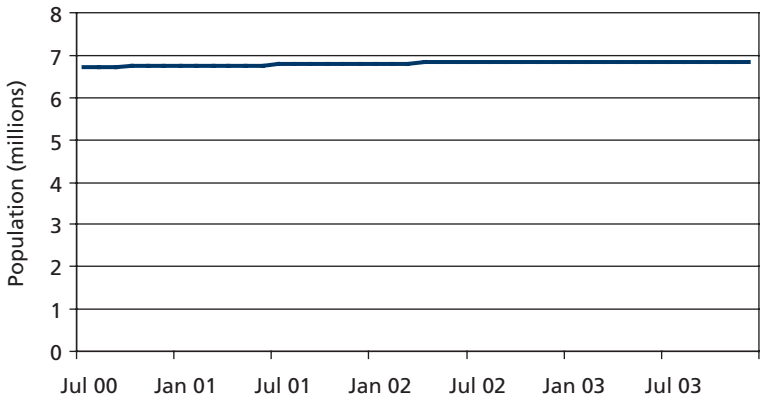

Figure 4. Hong Kong population, July 2000 to December 2003.

Table 2. Date of Chinese New Year — 2000 to 2004.

Year	Date
2000	05 February
2001	24 January
2002	12 February
2003	1 February
2004	22 January

The effects of the Asian Economic Crisis, which began with the forced devaluation of Thailand's baht in the second half of 1997, could not be estimated as the data is not available prior to 2000. However, the data does span the years in which SARS swept through Asia and other areas of the world. SARS created a short-term impact on demand, with local consumption and the export of services related to tourism and air travel severely affected. The outbreak started in the Chinese province of Guangdong in November 2002 and was first reported in Hong Kong in February 2003. Hong Kong was removed from the World Health Organization's SARS infected areas list by the end of June 2003.

Demand for live reef fish in aggregate

Results of the linear regression analysis for live reef fish in aggregate are shown in Table 3. The overall model is significant (although the F-statistic is low) with a relatively strong adjusted-R^2 for time-series data. However, all coefficient estimates except for the Chinese New Year (CNY) dummy variable, are insignificant. This indicates that consumption is relatively unaffected by changes in price, income and population, and due to the outbreak of SARS. It is estimated that

quantity demanded increases during Chinese New Year by approximately 260 tonnes. While the income elasticity is very low, and the population elasticity is very high, the coefficients relating to these variables are insignificant, hence these elasticity measures may be misleading. Note that there is no evidence of autocorrelation (the p-value of the Durban-Watson statistic is 0.94), and estimation of per capita demand and an inverse demand function provided similar results as those presented in Table 3.

Table 3. Estimated demand coefficients and calculated elasticities for aggregated live reef fish.

Variable	Estimated coefficient	*t*-statistic	Calculated elasticity
Price	–5 384.40	1.61	–0.44
CNY dummy	259 517.50	*3.70****	
GDP per capita	1.38	0.16	0.08
Population	0.64	0.34	5.09
SARS dummy	–114 341.00	1.58	
Model *F* statistic:	3.13		
Model *p*-value:	0.02		
Adj-R^2:	0.21		
Number of observations:	42		

Note: *** indicates significance at the 1% level, two-tailed test.

Demand for live reef fish — disaggregated into low-, medium- and high-valued species

The quantity and price data were disaggregated into low-, medium- and high-value species as shown in Table 1. The quantity imported and weighted average prices of these categories through time are shown in Figures 5 and 6. Import quantities of the high-value species are extremely small compared with the low- and medium-value species. Import quantities seem to be relatively constant over time, with low-value species increasing slowly and medium-value species decreasing slowly. The prices of low- and medium-value species are relatively constant through time compared with the high-value species, whose price trended upward until early 2001 and down since then. There is some evidence of a slow increase in prices of medium-value species.

Results of linear regression analyses for each price category are shown in Table 4, and the calculated elasticities are shown in Table 5. Each of the overall models for each category are significant, however, all estimates except for the Chinese New Year (CNY) dummy variable (in the case of the low-value and medium-value categories) and the cross-price variables (in the case of the high-value category), are insignificant. The results indicate that during Chinese New Year, the quantity demanded increases by approximately 135 000 kg and 112 000 kg, for the low- and medium-value categories, respectively. The different signs of the cross-price elasticities (in the case of the medium- and high-value categories) is difficult to explain and may be due to too few observations. The positive sign of the own-price elasticity for the high-value species is unexpected and may indicate that they are Veblen goods, that is, goods whose consumption increases as a direct function of its price (Leibenstein, 1950). Consumers may be willing to purchase higher quantities as price increases, as a gesture of prestige and favour. This relationship will be investigated further in the next section.

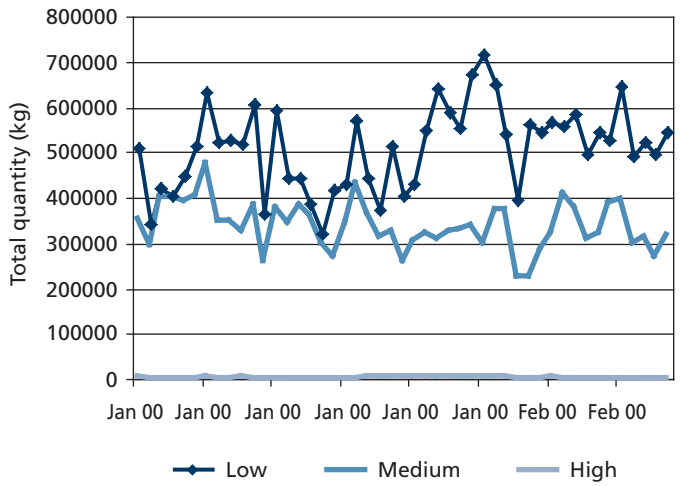

Figure 5. Quantity of live reef fish imported into Hong Kong divided into low-, medium- and high-value categories.

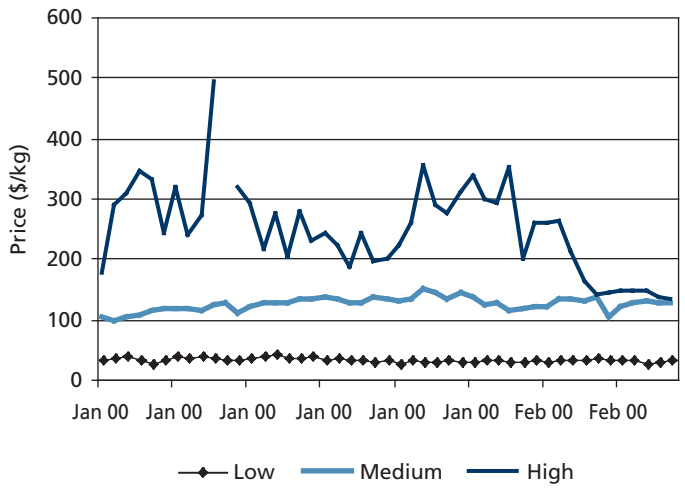

Figure 6. Weighted average price of live reef fish imported into Hong Kong divided into low-, medium- and high-value categories.

Table 4. Estimated demand coefficients for low-, medium- and high-value live reef fish.

Variable	Low-value		Medium-value		High-value	
	Estimated coefficient	*t*-statistic	Estimated coefficient	*t*-statistic	Estimated coefficient	*t*-statistic
Price — Low value	–4 423.42§	0.96	1 080.21	0.44	–156.66	2.47**
Price — Med value	1 947.14	1.11	–428.96§	0.46	46.67	1.94*
Price — High value	248.04	1.06	–9.04	0.07	2.73§	0.85
CNY dummy	135 330.90	2.44**	112 172.80	3.85***	977.02	1.29
GDP per capita	0.89	0.13	3.61	1.01	–0.10	1.04
Population	0.45	0.68	–0.17	0.49	–0.00	0.43
SARS dummy	63.27	0.00	–42 841.00	1.36	–474.63	0.58
Model *F* statistic:	2.42		3.56		2.68	
Model *p*-value:	0.04		0.01		0.03	
Adj-R^2:	0.20		0.31		0.23	
Number of observations:	41		41		41	

Note: ***, ** and * indicate significance at the 1%, 5% and 10% level, respectively.

§ indicates own-price coefficients.

Table 5. Calculated elasticities for low, medium and high-value live reef fish.

Variable	Low-value	Medium-value	High-value
Price — Low value	–0.30§	0.11	–2.54
Price — Med value	0.47	–0.16§	2.79
Price — High value	0.12	–0.01	0.33§
GDP per capita	0.09	0.52	–2.29
Population	5.96	–3.46	–12.89

Note: § indicates own-price elasticities.

Demand for live reef fish — individual species

The estimated demand coefficients and calculated elasticities for the low-value species are provided in Tables 6 and 7, respectively. Each of the models are significant except for flowery grouper. All species show a negative impact of price on quantity demanded. All species show inelastic demand, except forgreen grouper, which is a low-value species imported in relatively high quantities. 'Other marine fish' results show only one significant variable, the cross-price coefficient for high-value species. Results for mangrove snapper suggest that Chinese New Year, GDP per capita, population and SARS all influence quantity demanded. For GDP per capita, it is implied that as income grows consumption decreases, perhaps as consumers substitute high-value for lower and medium-value species. Green grouper results show two significant variables, own-price and Chinese New Year. No variables were significant in the analysis for flowery grouper.

Results for a preferred model (defined as the most significant model where all independent variables are significant and explicable) are presented in Table 8. Green grouper is the only low-value species where own-price affects demand. Chinese New Year has a significant influence on demand for mangrove snapper and green grouper. Results indicate that SARS has a negative impact on mangrove snapper demand, but no significant effect on the other species. Medium-value species appear to be substitutes for 'other marine fish'. Data limitations prevent the analysis of a preferred model for flowery grouper.

Tables 9 and 10 display results for estimated demand coefficients and calculated elasticities for medium-value species, respectively. The models for giant grouper and spotted coral trout are not significant. Each of the species in this category show negative own-price elasticities except for leopard coral trout, which seems to defy the law of diminishing demand. This may be due to data limitations, but also may be representative of Veblen good type qualities, where the higher the price, the more people are willing to consume as a show of favour and prestige. Leopard coral trout is popular due to its red colour — a colour symbolising good fortune in Chinese culture.

The results for a preferred model for each of the medium-value species are shown in Tables 11 and 12. Own-price effects are important for 'other groupers', tiger grouper and leopard coral trout. Cross-price effects are important for 'other groupers' and spotted coral trout. The population elasticity is inexplicably high for tiger grouper. GDP per capita has a significant positive impact on leopard coral trout. If this species is a Veblen good, then it is intuitive that demand increases as GDP per capita increases.

Regression results for high-value species are provided in Tables 13 and 14. Both of these species appear to defy the law of diminishing demand. The own-price elasticity is not significant for humphead wrasse, but is positive and strongly significant for humpback grouper. Cross-price elasticities are important for both species.

Table 6. Estimated demand coefficients for the low-value live reef fish species.

Variable	Other marine fish		Mangrove snapper		Green grouper		Flowery grouper	
	Estimated coefficient	*t*-statistic	Estimated coefficient	*t*-statistic	Estimated coefficient	*t*-statistic	Estimated coefficient	*t*-statistic
Own-price	–6.05	1.11	–27.60	0.15	–5 554.67	3.03***	–26.75	0.36
Price — Med value	2 325.46	1.49	47.10	0.22	–404.76	0.64	–13.19	0.09
Price — High value	358.85	1.85*	–4.00	0.15	–86.20	1.02	–0.54	0.03
CNY dummy	62 985.00	1.40	13 884.60	2.29**	61 307.21	3.14***	–1546.29	0.32
GDP per capita	2.33	0.41	–2.48	3.11***	1.56	0.64	–0.01	0.02
Population	0.64	1.23	–0.28	3.52***	–0.36	1.22	–0.01	0.11
SARS dummy	18 164.86	0.63	–16 388.80	2.3**	11 150.61	0.51	–1428.30	0.29
Model *F* statistic:	2.96		11.35		3.03		0.14	
Model *p*-value:	0.02		0.00		0.01		0.99	
Adj-R^2:	0.26		0.66		0.26		–0.18	
Number of obs:	41		35		41		41	

Note: ***, ** and * indicate significance at the 1%, 5% and 10% level, respectively.

Table 7. Calculated elasticities for the low-value live reef fish species.

Variable	Other marine fish	Mangrove snapper	Green grouper	Flowery grouper
Own-price	–0.00	–0.05	–2.70	–0.18
Price — Med value	0.80	0.28	–0.42	–0.14
Price — High value	0.25	–0.05	–0.180	–0.01
GDP per capita	0.32	–5.64	0.64	–0.05
Population	12.02	–87.80	–20.67	–3.22

Table 8. Estimated demand coefficients and calculated elasticities for the low-value live reef fish species — preferred model.

Variable	Other marine fish			Mangrove snapper			Green grouper		
	Estimated coefficient	*t*-statistic	Calculated elasticity	Estimated coefficient	*t*-statistic	Calculated elasticity	Estimated coefficient	*t*-statistic	Calculated elasticity
Own-price	–	–	–	–	–	–	–2 416.08	2.85***	–1.18
Price — Med value	3024.99	3.23***	1.04	–	–	–	–	–	–
Price — High value	–	–	–	–	–	–	–	–	–
CNY dummy	–	–	–	23 049.46	2.49**	–	48 160.73	3.10***	–
GDP per capita	–	–	–	–	–	–	–	–	–
Population	–	–	–	–	–	–	–	–	–
SARS dummy	–	–	–	–19 024.24	2.59**	–	–	–	–
Model *F* statistic:	10.44			5.45			8.89		
Model *p*–value:	0.00			0.01			0.00		
Adj-R^2:	0.17			0.17			0.26		
Number of observations:	47			45			47		

Note: ***, ** and * indicate significance at the 1%, 5% and 10% level, respectively.

Table 9. Estimated demand coefficients for the medium-value live reef fish species.

Variable	Other groupers		Tiger grouper		Giant grouper		Spotted coral trout		Leopard coral trout	
	Est. coeff.	*t*-stat	Est. coeff.	*t*-stat	Est. coeff.	*t*-stat	Est. coeff.	*t*-stat	Est. coeff.	*t*-stat
Own-price	–380.21	1.08	–363.04	3.89***	–15.31	0.28	–26.82	0.96	775.39	1.01
Price — Low	775.87	0.44	451.38	1.56	15.41	0.10	192.82	1.62	–173.67	0.10
Price — High	–42.87	0.48	–14.97	1.07	2.77	0.40	2.62	0.46	72.52	0.88
CNY dummy	42 168.71	1.97*	6270.76	1.77*	–124.15	0.05	497.70	0.34	47 365.59	1.93*
GDP per capita	–4.95	1.88*	–0.68	1.41	–0.08	0.34	0.13	0.72	7.40	2.85***
Population	–0.62	3.10***	0.14	4.81***	0.00	0.34	–0.02	1.23	0.23	1.17
SARS dummy	–8 327.79	0.40	–8265.35	2.21**	3092.77	2.02**	–580.01	0.40	–27 084.00	1.27
Model *F* stat:	6.44		6.6		1.47		1.47		3.97	
Mod *p*-value:	0.00		0.00		0.24		0.21		0.00	
Adj-R^2:	0.49		0.50		0.12		0.08		0.34	
Number of observations:	41		41		26		41		41	

Note: ***, ** and * indicate significance at the 1%, 5% and 10% level, respectively.

Table 10. Calculated elasticities for the medium-value live reef fish species.

Variable	Other groupers	Tiger grouper	Giant grouper	Spotted coral trout	Leopard coral trout
Own-price	–0.26	–2.87	–0.74	–0.48	0.64
Price — Low value	0.19	1.23	0.25	0.82	–0.03
Price — High value	–0.08	–0.30	0.33	0.08	0.10
GDP per capita	–1.76	–2.70	–1.76	0.83	2.02
Population	–30.34	75.37	14.76	–13.70	8.78

Table 11. Estimated demand coefficients for the medium-value live reef fish species — preferred model.

Variable	Other groupers		Tiger grouper		Spotted coral trout		Leopard coral trout	
	Est. coeff.	*t*-stat	Est. coeff.	*t*-stat	Est. coeff.	*t*-stat	Est. coeff.	*t*-stat
Own-price	–850.52	2.63**	–312.94	3.89***	–	–	1699.20	3.05***
Price — Low value	4790.85	2.88***	–	–	340.64	3.32***	–	–
Price — High value	177.43	2.14**	–	–	–	–	–	–
CNY dummy	–	–	8529.79	2.41**	–	–	–	–
GDP per capita	–	–	–	–	–	–	6.50	3.06***
Population	–	–	0.13	5.19***	–	–	–	–
SARS dummy	–	–	–6581.05	2.19**	–	–	–	–
Model *F* statistic:	6.50		9.44		11.04		10.47	
Model *p*-value:	0.00		0.00		0.00		0.00	
Adj-R^2:	0.27		0.45		0.18		0.32	
Number of obs:	46		42		47		42	

Note: ***, ** and * indicate significance at the 1%, 5% and 10% level, respectively.

Table 12. Calculated elasticities for the medium-value live reef fish species — preferred model.

Variable	Other groupers	Tiger grouper	Spotted coral trout	Leopard coral trout
Own-price	–0.059	–2.47	–	1.39
Price — Low value	1.16	–	1.44	–
Price — High value	0.32	–	–	–
GDP per capita	–	–	–	1.78
Population	–	69.52	–	–

Table 13. Estimated demand coefficients and calculated elasticities for the high-value live reef fish species.

Variable	Humphead wrasse			Humpback grouper		
	Est. coefficient.	*t*-statistic	Calc. elasticity	Est. coefficient.	*t*-statistic	Calc. elasticity
Own-price	0.49	0.20	0.07	1.42	1.61	0.60
Price — Low value	–132.27	2.68**	–2.93	–17.38	0.67	–0.88
Price — Med value	27.75	1.42	2.28	22.20	2.48**	4.15
CNY dummy	275.61	0.46	–	667.03	2.23**	–
GDP per capita	–0.11	1.48	–3.53	0.02	0.39	1.13
Population	0.00	0.36	–11.58	0.00	0.18	–6.58
SARS dummy	–747.26	1.15	–	247.88	0.77	–
Model *F* statistic:	2.19			3.03		
Model *p*-value:	0.06			0.02		
Adj-R^2:	0.17			0.27		
Number of obs:	41			39		

Table 14. Estimated demand coefficients and calculated elasticities for the high-value live reef fish species — preferred model.

Variable	Humphead wrasse			Humpback grouper		
	Est. coefficient.	*t*-statistic	Calc. elasticity	Est. coefficient.	*t*-statistic	Calc. elasticity
Own-price	–	–	–	1.81	2.79***	0.76
Price — Low value	–80.96	2.14**	–1.8	–	–	–
Price — Med value	24.01	2.08**	1.97	21.08	3.50***	3.94
CNY dummy	–	–	–	649.73	2.44**	–
GDP per capita	–	–	–	–	–	–
Population	–	–	–	–	–	–
SARS dummy	–	–	–	–	–	–
Model F statistic:	5.40			8.08		
Model p-value:	0.01			0.00		
Adj-R2:	0.16			0.34		
Number of obs:	46			42		

Note: ***, ** and * indicate significance at the 1%, 5% and 10% level, respectively.

Conclusions

Import demand functions for live reef fish in Hong Kong were estimated using single equation linear regression analysis. The aim of the paper is to conduct initial data exploration before estimating demand systems for the fishery. Monthly time-series data from July 2000 to May 2003 were obtained from the Hong Kong AFCD. A number of independent variables were used, including prices (own-price as well as prices of other live reef fish species), income (GDP per capita), population of Hong Kong and dummy variables to account for the month in which the Chinese New Year festival is held and the outbreak of SARS.

Estimation was performed in three stages. First, import demand was estimated for all live reef fish species in aggregate. The own-price elasticity for the estimated demand function was inelastic and insignificant. The only significant variable in the estimated function was the Chinese New Year dummy variable, indicating that quantity demanded increases by approximately 250 tonnes during Chinese New Year.

In the second stage, the live reef fish species were categorised as either low-, medium- or high-value species, and three separate demand functions were estimated. In the case of the low- and medium-value species, the own-price elasticities were negative, inelastic and insignificant. Quantity demanded for these low- and medium-value species was affected by the occurrence of Chinese New Year alone. In the case of the high-value species, the own-price elasticity was positive, elastic and strongly significant. Quantity demanded was also shown to be affected by the price of substitutes (low- and medium-value live reef fish species).

The third stage of the analysis was to estimate demand functions for each species separately. Of the eleven species estimated, the eight lowest priced species all exhibited negative own-price elasticities and the three highest priced species (leopard coral trout, humphead wrasse and humpback grouper) all exhibited positive own-price elasticities. A preferred model (defined as the most significant model where all independent variables are significant and explicable)

was estimated for each species. The own-price and cross-price elasticities and Chinese New Year impacts were significant for many of the low-, medium- and high-value species. There was evidence of significant negative impacts of SARS on mangrove snapper and tiger grouper. Leopard coral trout showed significant and positive impact from its own-price and GDP per capita.

In summary, the own-price elasticity was not as strong an indicator of import demand as was expected. Chinese New Year was a stronger indicator of import demand than price, and income had very little influence (although there was very little change in income over the time period making it difficult to draw out any trends). This may be a result of problems with data (the number of observations ranged from 35 to 47 depending on the species). It also may indicated the unique nature of live reef fish, where consumption is determined by cultural events and is largely unrelated to price and income.

The positive impact of price on import demand for the three highest valued species may be a result of data limitations, or it may be reflecting the 'prestigious' nature of these species. They are consumed in especially high quantities in celebration of a lunar festival (in the case of Chinese New Year) or to celebrate other occasions such as the closing of a business deal or to honour a favoured visitor. In these cases, the level of honour placed upon the occasion is positively related to the price of the live reef fish consumed. This positive correlation is evidenced in a significant positive impact of price on import demand for these species in Hong Kong. As such they are Veblen goods. In our analysis, they include leopard coral trout, humphead wrasse (the most endangered species) and humpback grouper.

Further analysis must be conducted to verify these findings. Demand systems should be estimated in case changes in the price of goods omitted from the specification are causing changes in demand for the commodity in question through changes in expenditure. Moreover, this estimation should be repeated in the future when more observations are available. Lastly, there is evidence that the price received for live reef fish depends on the country of origin. Estimation of demand systems by origin would provide useful information on these price differences.

References

Agriculture, Forestry and Conservation Department (AFCD).2003. Report on Live Marine Fish Trade. Government of Hong Kong, Hong Kong.

Asche F. 1996. A system approach to the demand for salmon in the European Union. Applied Economics, 28: 97–101.

Asche F. and Bjorndal T. 1999. Demand elasticities for fish: A review. Available at https://www.globefish.org/publications/speicalseries/vols/Vol09/SSE0800.htm as at July 2003.

Asche F., Bjorndal T. and Young J.A. 2001. Market interactions for aquaculture products. Aquaculture Economics and Management, 5(5/6): 303–318.

Bird, P. 1986. Econometric estimation of world salmon demand. Marine Resource Economics, 3: 169–182.

Cesar H.S.J., Warren K.A., Savody Y., Lau P., Meijer S. and van Ierland E. 2000. Marine market transformation of the live reef fish food trade in Southeast Asia. In Cesar, H.S.J. (Ed) Collected Essays on the Economics of Coral Reefs. Sweden: CORDIO.

Deaton A.S. and Muellbauer J. 1980. An almost ideal demand system. American Economic Review, 70: 312–326.

DeVoretz D. 1982. An econometric demand model for Canadian Salmon. *Canadian* Journal of Agricultural Economics, 30: 49–60.

DeVoretz D.J. and Salvanes K.G. 1993. Market structure for farmed salmon. American Journal of Agricultural Economics, 79: 227–233.

Economist Intelligence Unit (EIU). 2003 Country Report: Hong Kong, EIU, London.

Herrmann M.L. and Lin B.H. 1988. The demand and supply of Norwegian Atlantic salmon in the United States and the European Community. Canadian Journal of Agricultural Economics, 38: 459–471.

Herrmann M.L., Mittelhammer R.C. and Lin B.H. 1993. Import demand for Norwegian farmed Atlantic salmon and wild Pacific salmon in North America, Japan and the EC. Canadian Journal of Agricultural Economics, 41: 111–125.

Jaffry S., Pascoe S., Taylor G. and Zabala U. 2000. Price interactions between salmon and wild caught fish species on the Spanish market, Aquaculture Economics and Management, 4(3/4): 157–167).

Kabir M. and Ridler N.G. 1984. The demand for Atlantic salmon in Canada. Canadian Journal of Agricultural Economics, 32: 560–568.

Leibenstein H. 1950. Bandwagon, snob, and Veblen effects in the theory of consumers' demand. Quarterly Journal of Economics, 64: 183–207.

Muldoon G.J and McGilvray F. 2004. Economic and trade issues, p 19–41. In J. Maclean and Y. Sadovy, (eds). The live reef fish rtrade. ABD Pacific Studies Series. Asian Development Bank, Manila.

Sadovy Y.J. and Vincent A.C.J. 2002. Ecological issues and the trades in live reef fishes. In Coral Reef Fishers Elsevier Science, USA.

Salvanes K.G. and DeVoretz D.J. 1997. Household demand for fish and meat products: separability and demographic effects. Marine Resource Economics, 12: 37–55.

Sloman J. and Norris K. 2002. Economics 2nd Edition. Pearson Education Australia, New South Wales.

Smith A. 2004. Social issues, p 61-72. In J. Maclean and Y. Sadovy, (eds). The Live Reef Fish Trade. ABD Pacific Studies Series. Asian Development Bank, Manila.

Wallstrom P. and Wessells C.R. 1995. Analysis of U.S. consumer demand for canned tuna: Impact of dolphin-safe controversy. In D.S. Liao, Ed) International Cooperation for Fisheries and Aquaculture Development: Proceedings of the 7th Biennial Conference of the International Institute of Fisheries Economics and Trade, Vol 3.

Wing C.K. and On W.H.K. 2002. A time-series analysis of the price of Epinephelus. Aquaculture Economics and Management, 6(3/4): 216–229.

12. Aquaculture of groupers in Asia and the Pacific

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Introduction

Aquaculture production of groupers continues to expand rapidly, at 10–77% per annum since 1999 (Table 1). This expansion is fuelled by a consistent demand for a range of high-value species sold live, with the major markets in Hong Kong and China. Although there is a range of farmed marine finfish supplied to the live reef food fish trade (Lau and Li, 2000), this paper focuses on groupers. Groupers are amongst the highest value species in the trade and consequently are the fish favoured by farmers. In addition, groupers have been the focus of much recent research and development aimed at increasing the supply from aquaculture. Snappers (Lutjanidae) are also in demand in live fish markets, but because they generally bring lower prices than groupers there has been less emphasis on snapper species. Many snappers are produced for local markets, rather than the 'high-end' export markets in Hong Kong and southern China.

In this paper we use the Food and Agriculture Organisation (FAO) definition of aquaculture, i.e. aquatic farming activity that 'implies some sort of intervention in the rearing process to enhance production, such as regular stocking, feeding, protection from predators, etc.' With regard to the live reef food fish trade, this definition covers a range of activities from full-cycle aquaculture to short-term holding and feeding of fish to 'fatten' them or to take advantage of market price fluctuations.

Grouper aquaculture production and value

FAO data for aquacultured groupers (FAO, 2005) indicate a total production of around 52 000 tonnes in 2003 (Table 1). Additional grouper production from Vietnam (which is not reported separately from other marine finfish production) is likely around 2000 tonnes per annum, bringing total global production to around 54 000 tonnes. Most aquaculture production of groupers is from Southeast Asia, with the largest producers China, Taiwan, Indonesia, Malaysia and Thailand (Table 1). There is no significant production from Pacific Island countries.

The global value of aquaculture production of groupers (FAO, 2005) was around US$238 million in 2003, omitting Vietnam production (Table 2).

Species cultured

All groupers, by definition, belong to the subfamily Epinephelinae of the family Serranidae. There is some small production (grow-out from wild caught juveniles) of the smaller groupers, such as *Cephalopholis* spp. but most aquaculture focuses on the larger species of the genera *Epinephelus*, *Cromileptes* and *Plectropomus*. The following briefly describes some of the most commonly farmed grouper species.

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Table 1. Grouper aquaculture production from 1970 to 2003 (metric tonnes).

Country	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
Brazil	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
China	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
China, Hong Kong SAR	30	65	80	100	110	105	122	123	149	155	163	197	215	195	230	243	336	754	410	310
Indonesia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Korea, Republic of	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Kuwait	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Malaysia	0	0	0	0	0	0	0	0	0	0	16	12	9	28	18	28	99	107	146	169
Philippines	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Saudi Arabia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Singapore	0	0	0	0	0	0	0	0	0	0	0	14	175	156	114	94	129	129	141	163
Taiwan Province of China	0	0	0	0	0	0	0	0	0	0	0	0	0	0	203	838	971	1224	1067	408
Thailand	0	0	1	10	26	45	62	71	81	93	107	175	140	180	149	117	161	343	358	447
Tunisia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
United Arab Emirates	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0.5	0.5
United States of America	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	**30**	**65**	**81**	**110**	**136**	**150**	**184**	**194**	**230**	**248**	**286**	**398**	**539**	**559**	**714**	**1320**	**1696**	**2558**	**2123**	**1498**
Annual increase (%)		**117%**	**25%**	**36%**	**24%**	**10%**	**23%**	**5%**	**19%**	**8%**	**15%**	**39%**	**35%**	**4%**	**28%**	**85%**	**28%**	**51%**	**–17%**	**–29%**

Country	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Brazil	0	0	0	0	0	0	0	0	1	2	3	3	3	3
China	0	0	0	0	0	0	0	0	0	0	0	0	0	26 790
China, Hong Kong SAR	365	265	55	632	627	620	1110	1036	312	280	523	910	325	832
Indonesia	0	0	0	0	0	0	0	0	0	1759	1159	3 818	7 057	8 665
Korea, Republic of	0	0	0	0	0	0	9	0	0	5	6	20	39	101
Kuwait	0	0	0	0	0	0	0	0	0	5	6	3	3	3
Malaysia	144	153	288	1006	931	834	857	799	465	948	1217	1 101	1 399	1 977
Philippines	2363	6765	349	772	2129	715	595	645	135	151	167	136	118	449
Saudi Arabia	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Singapore	185	198	233	147	133	101	93	82	97	94	111	88	64	92
Taiwan Province of China	2206	1229	1125	3942	1841	2104	1883	2525	3471	4122	5053	5 386	12 367	11 564
Thailand	415	355	965	755	1078	674	774	795	1390	1143	1332	1 442	1 442	1 442
Tunisia	0	0	2	1	1	<0.5	<0.5	<0.5	0	0	0	0	0	0
United Arab Emirates	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Unites States of America	0	0	0	0	0	0	0	0	0	0	0	0	0	11
Total	**5679**	**8966**	**3018**	**7256**	**6741**	**5049**	**5322**	**5883**	**5873**	**8510**	**9578**	**12 908**	**22 817**	**51 929**
Annual increase (%)	**279%**	**58%**	**–66%**	**140%**	**–7%**	**–25%**	**5%**	**11%**	**0%**	**45%**	**13%**	**35%**	**77%**	**128%**

Figures are FAO data for Serranidae in brackishwater and mariculture. Data originally listed as '<0.5' have been changed to 0.5, and from '–' to 0. Philippines data for 1990 and 1991 are anomalous, and the bulk of these data represent 'brackishwater' production.

Vietnam data are not reported separately, but are included in marine finfish production data. Vietnam produced an estimated 2600 tonnes of marine fish in 2001 of which a high proportion is cultured groupers (Le, 2002). Grouper production data for China are available only from 2003; previous production is included in marine finfish data. Relative increase in grouper production for 2003, omitting China data, is 10%.

Table 2. Grouper aquaculture value from 1986 to 2003 (US$ millions).

Country	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Brazil	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
China	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	53.6
China, Hong Kong SAR	5.1	12.0	8.8	6.3	5.6	4.7	1.1	12.9	12.9	12.0	20.1	20.1	5.3	3.4	7.1	13.3	4.2	9.2
Indonesia	0	0	0	0	0	0	0	0	0	0	0	0	0	6.2	4.4	13.4	38.3	79.7
Korea, Republic of	0	0	0	0	0	0	0	0	0	0	0.1	0	0	0.2	0.2	0.5	0.8	2.3
Kuwait	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Malaysia	0.5	0.6	0.7	0.5	0.7	1.1	1.2	10.3	10.6	10.9	11.9	10.3	1.4	4.3	6.9	6.3	8.1	13.1
Philippines	0	0	0	0	5.9	47.2	4.5	4.7	26.6	9.0	6.7	6.3	1.1	1.0	1.1	0.8	0.9	1.4
Saudi Arabia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Singapore	1.2	1.2	1.3	1.6	1.8	2.0	2.5	2.6	2.0	1.4	1.5	1.1	1.1	1.0	1.2	0.9	0.7	1.4
Taiwan Province of China	3.6	8.0	5.3	4.3	12.5	7.5	7.6	19.6	15.6	26.0	15.4	26.4	27.3	37.6	34.6	41.1	54.9	66.0
Thailand	0.6	1.3	3.2	3.4	2.1	2.1	12.5	9.4	13.5	8.3	9.8	8.8	8.7	9.7	10.7	11.5	11.5	11.5
Tunisia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
United Arab Emirates	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
United States of America	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1
Total	**11.0**	**23.1**	**19.3**	**16.1**	**28.6**	**64.6**	**29.4**	**59.5**	**81.2**	**67.6**	**65.5**	**73.0**	**44.9**	**63.4**	**66.2**	**87.8**	**119.4**	**238.3**

Figures are FAO data for Serranidae in brackish water and mariculture. Data originally listed as '–' have been changed to 0. Data for Vietnam are not included. Data for China are available only from 2003.

Epinephelus coioides (green grouper, greasy grouper, estuary cod, gold-spot cod)

This species is frequently misidentified in the aquaculture literature as *E. tauvina* or *E. malabaricus* and is sometimes incorrectly named *E. suillis* (a synonym). *Epinephelus coioides* grows rapidly in culture and reaches market size (around 500 g) in 9–12 months. It is a hardy species and can tolerate substantial variations in water quality, including salinity, reflecting its estuarine habitat in the wild. Most aquaculture production now comes from hatchery-produced fingerlings, with Taiwan probably the largest producer of fingerlings.

Epinephelus fuscoguttatus (tiger grouper, flowery cod)

This is a medium-priced species in the live reef fish trade. Fingerlings are in demand by farmers in Southeast Asia because this species survives well and grows rapidly in culture, reaching market size (around 500 g) in 9–12 months. Increasing numbers of hatchery-reared fingerlings are being produced in Indonesia, Malaysia and Taiwan, leading to substantial increases in aquaculture production in the short term.

Epinephelus polyphekadion (camouflage grouper)

This species is a mainstay of the live reef food fish trade with wild-captured fish being sourced mainly from the Pacific. Although hatchery production technology exists for *E. polyphekadion*, there is little demand from farmers because of its relatively slow growth rate in culture.

Epinephelus malabaricus (Malabar grouper)

Despite common mention in the scientific literature, this species is not often cultured. Taiwanese farms reported that the breeding season for *E. malabaricus* is short, which limited production, so they switched to other species such as *E. coioides* (Rimmer, 1998). Much of the Thai literature that mentions *E. malabaricus* most likely refers to *E. coioides*. Due to the taxonomic confusion surrounding Epinephelus species, it is difficult to assess the quantities of *E. malabaricus* cultured.

Epinephelus lanceolatus (king grouper, giant grouper, Queensland grouper)

This species is an increasingly popular aquaculture candidate because of its rapid growth rate to around 3 kg in the first year. Little information is available on grow-out of this species, but its estuarine habitat in the wild suggests that it would tolerate a wide range of water quality conditions, and would make a good candidate for coastal aquaculture.

Epinephelus tukula (potato cod)

Epinephelus tukula has only recently appeared as an aquaculture species, with some experimental culture in Taiwan. A large and aggressive species, there is as yet no information on its commercial culture. Anecdotal reports indicate that this species has a slow growth rate and consequently may not be in demand by farmers.

Epinephelus akaara (red grouper)

Epinephelus akaara is widely cultured in coastal areas throughout Southeast Asia. Fingerling supply is from both wild-caught and hatchery-reared fish. This is a high-value species in the live fish markets of Hong Kong and southern China.

Other farmed *Epinephelus* species

There is a range of other *Epinephelus* species that are caught as juveniles and grown out for the live reef food fish trade. These include:

- *Epinephelus areolatus* (brown-spotted grouper)
- *Epinephelus awoara* (yellow grouper)
- *Epinephelus bleekeri* (duskytail grouper)
- *Epinephelus multinotatus* (white-blotched grouper).

Cromileptes altivelis (polka-dot grouper, mouse grouper, barramundi cod)

This species is a popular aquaculture candidate because of it is a high value in the live reef fish trade. Juvenile fish are in demand as aquarium inhabitants. This species is relatively slow growing, taking 1.5–2 years to reach market size. There is substantial fingerling production from Indonesian hatcheries, but the slow growth rate and its relatively delicate nature in culture limits its appeal to farmers.

Plectropomus spp. (coral trout)

Most culture of coral trout species is based on capture of wild-caught fingerlings. There is limited production of hatchery-reared juveniles in Japan (for restocking reefs in the south) and recently Taiwan reported success with the large-scale production of this species (Su, 2005). There has been some success in research hatcheries in Indonesia and Thailand in producing juveniles of two species: *P. maculatus* and *P. leopardus*.

Cephalopholis spp.

These small groupers (coral cods) are farmed in small quantities from wild-caught fingerlings.

Cheilinus undulatus (humphead wrasse, Napoleon wrasse, Maori wrasse)

Not a grouper, but a member of the unrelated wrasse family (Labridae), the humphead wrasse is commonly listed alongside high-value grouper species because it is a premium species in the live reef food fish trade. All production currently comes from wild-caught juveniles and sub-adults. In 2004, the Gondol Research Institute for Mariculture in Bali, Indonesia, produced the first hatchery-reared humphead wrasse, but there is as yet no commercial hatchery production. The very slow growth rate of these juveniles suggests that there is limited aquaculture potential for this species. *Cheilinus undulatus* was recently listed on Appendix II of the Convention on International Trade in Endangered Species (CITES) which is likely to restrict trade of this species (Sadovy, 2005).

New species

Several new grouper species are being bred on an experimental basis in Taiwan. These include: *E. multinotatus*, *E. flavocaeruleus*, *E. cyanopodus* and *Cephalopholis sonnerati* (Kao, 2004).

Production systems

Fingerling production

Although there is increasing hatchery production of fingerlings of several species, much of the aquaculture production of groupers still comes from fish that are captured from the wild as juveniles, and grown out in cages or in ponds in coastal areas (Johannes and Ogburn, 1999; Sadovy, 2000; Estudillo and Duray, 2003). However, supplies of naturally recruited fingerlings are limited by fingerling availability (which in many cases has been reduced through overfishing), and high mortality of captured fry, particularly the 'tinies' or pre-metamorphic larvae (Estudillo and Duray, 2003). The fry/fingerling trade is complex and widespread in Asia. Sadovy (2000) estimated that the annual grouper fry/fingerling catch is in the hundreds of millions. A regional survey concluded that there were indications that grouper fry and fingerling supplies had declined in many areas, and that these declines likely involved overfishing of grouper adults and seed, habitat destruction, destructive fishing practices, pollution and high export demand (Sadovy, 2000).

The proportion of hatchery-reared versus wild-caught fingerlings varies between countries: it may be as high as 75% hatchery-reared fingerlings in Taiwan, and effectively 100% wild-caught fingerlings in many countries, including the Philippines. Overall, we estimate that 15–25% of the global production of groupers is from hatchery-reared fingerlings. This proportion is likely to increase as more hatcheries start production and overfishing continues to limit the numbers of wild-caught juveniles that are available.

Historically, hatchery production of groupers has been constrained by poor and unreliable survival of larvae in hatcheries (Rimmer *et al.*, 2000). The major proportion of hatchery-produced grouper fingerlings originates from Taiwan, which has around 1000 farms involved in fry and juvenile production (Kao, 2004; Su, 2005). Marine finfish production in Taiwan is typified by highly specialised production sectors: e.g. one farm may produce grouper eggs from captive broodstock, a second will rear the eggs, a third may rear the juveniles through a nursery phase (to 3–6 cm total length (TL)) and a fourth will grow the fish to market size (Liao *et al.*, 1994; Kao, 2004).

Taiwanese hatcheries typically use either 'indoor' (concrete tanks up to 100 m^3 with intensive greenwater culture systems) or 'outdoor' (extensive pond culture systems) rearing systems for larviculture (Liao *et al.*, 2001). Indoor rearing systems are used for high-value species such as groupers and other species, such as some snappers and cobia (*Rachycentron canadum*), are only cultured in outdoor systems because of specific early feed requirements (Liao *et al.*, 2001). The main grouper species cultivated in Taiwan is the estuary grouper *E. coioides*. Taiwanese hatcheries produced around 25 million *E. coioides* fingerlings in 2002 and 2003, but production reportedly declined in 2004, presumably because of increasing demand for other grouper species ((Liao *et al.* 2001). More recently, there has been increasing production of giant grouper *E. lanceolatus* (Table 3) which is popular amongst farmers for its hardiness and its rapid growth. Fingerling production data for 2004 also indicate substantial production of *E. fuscoguttatus* and the first report of large-scale production of *Plectropomus leopardus* fingerlings (Table 3).

Table 3. Estimates of annual grouper fry production (millions) from Taiwanese hatcheries.

	2002	2003	2004
E. coioides	25.2	21.2	8.7
E. lanceolatus	–	2.5	2.5
E. fuscoguttatus	–	–	9.1
P. leopardus	–	–	0.4
Total	**25.2**	**23.7**	**20.7**

Source: (Su, 2005).

Large numbers of fingerlings produced in Taiwan are exported to other parts of Asia, principally China, Hong Kong, Malaysia, Thailand and Vietnam (Kao, 2004). Despite the high level of fingerling production, Taiwanese farms also rely on wild-caught fry and fingerlings, which are generally imported (Liao *et al.*, 1994; Sadovy 2000).

As production technology for groupers and other marine finfish species has improved, there has been increasing development of hatcheries and increasing hatchery production of several grouper species in Southeast Asia. For example, in Indonesia there is continuing expansion of hatchery production from 'backyard' hatcheries. There are an estimated 2000 units (1 unit = 4 larval rearing tanks) of backyard hatcheries in northern Bali, clustered around the Gondol Research Institute for Mariculture that introduced this technology in the 1990s (Siar *et al.*, 2002). The backyard hatcheries were originally established to rear fry of milkfish (*Chanos chanos*) for grow-out in other parts of Indonesia and the Philippines for the food and baitfish markets. Today, many backyard hatcheries also produce grouper fingerlings including *C. altivelis* and *E. fuscoguttatus*. Larger hatcheries maintain their own broodstock, and sell fertilised eggs to the smaller hatcheries. The hatcheries rear the grouper larvae to juvenile stage, generally 3–10 cm TL. In 2002, a total of 3.3 million grouper seedstock were produced by Indonesian hatcheries and this increased to over 4.8 million fingerlings in 2004 (Table 4). The juvenile fish are sold to grow-out farms in other parts of Indonesia or overseas; many juvenile *C. altivelis* are sold to the international aquarium fish market.

Table 4. Estimated annual production of grouper seedstock (5–10 cm TL) from Indonesian hatcheries in 2002.

	2002	2004
E. coioides	2 200	4 450
E. fuscoguttatus	2 656 200	3 800 700
C. altivelis	697 800	1 050 420
Total	**3 356 200**	**4 855 570**

Source: (Sugama, 2003) and (K. Sugama, *pers. comm.* 2004).

There is also increasing development of hatcheries in many other Southeast Asian countries, including China, Vietnam, Thailand, Malaysia and the Philippines. However, grouper culture in these countries (with the possible exception of China) is still largely based on collection of wild-caught fry and fingerlings or importation of fingerlings from Taiwan and Indonesia. In Vietnam, the cost of fingerlings varies depending on the source, species, size, season and region (Table 5). In Malaysia, wild-caught *E. fuscoguttatus* sell for about the same amount as hatchery reared fingerlings (Table 7). The major determinant of price appears to be species, with *E. lanceolatus* being the most expensive of those listed (Table 7). Grouper fingerling prices vary substantially between countries: in Myanmar fingerlings 10–12.5 cm TL cost US$7.50 and larger juveniles (25–27.5 cm TL) cost US$45 (Lay, 2002).

In Australia, grouper aquaculture remains largely experimental. One Queensland and one Western Australian hatchery have both produced small numbers of *E. coioides*, and one hatchery in northern Queensland has produced numbers of *C. altivelis*. While there is continuing interest in aquaculture of live reef food fish in Australia, the relatively risky nature of establishing such ventures and the severely regulated environment for aquaculture (in Australia) are currently limiting the development of this industry sector.

Table 5. Cost of wild-caught, imported and locally produced grouper fingerlings in Vietnam and Malaysia.

Country	Source	Species	Size	Cost (US$)
Vietnam	Wild-caught		8–10 cm	$0.40–0.80
	Imported		10–12 cm	$0.9
	Hatchery-reared		8–15 cm	$0.55–0.95
Malaysia	Wild-caught	*E. coioides E. bleekeri*	10 cm	$1.20
	Imported	*E. coioides*	7.5 cm	$0.66
		E. lanceolatus	7.5 cm	$3.70–$4.00
		E. fuscoguttatus	5 cm	$1.60–1.80
		C. altivelis	5 cm	$1.60
	Locally produced	*E. fuscoguttatus*	2.5–6.25 cm	$1.05–$1.65

Source: (Le, 2002) and (Awang, 2002).

There is little hatchery production of marine finfish fingerlings in the Pacific. There is one private company in Papua New Guinea producing barramundi/sea bass (*Lates calcarifer*) and planning to produce cobia (*Rachycentron canadum*). There is a small private hatchery at Savusavu (Fiji) that is targeting production of mangrove jack (*Lutjanus argentimaculatus*) and coral trout (*Plectropomus* spp.) (Ben Ponia, *pers. comm.*, 2004). A Korean company operates a sea-cage farm in Chuuk (Federated States of Micronesia) culturing wide-banded sea perch. Fingerlings are imported from Korea to be grown-out at the Chuuk facility, and harvested fish (500–600 g) are shipped live to the Japanese sashimi market (Henry, 2005).

Some recent developments in the Pacific and in the Caribbean have used light traps and crest nets to harvest pre-settlement juvenile or late larval fish and invertebrates for subsequent grow-out (Dufour, 2002; Hair *et al.*, 2002; Watson *et al.*, 2002). This mode of harvesting exploits the rationale that most fish and invertebrate species with pelagic larval stages are subject to extremely high mortality prior to and at settlement; and that harvesting a proportion of these will have negligible impacts on recruitment (Doherty, 1991; Sadovy and Pet, 1998). In comparison, natural mortality of settled fingerlings may be relatively low and the fisheries for these larger fingerlings may be subject to the same harvesting constraints as fisheries for adult fish (Sadovy and Pet, 1998). To date, these capture techniques have shown promise for the collection of aquarium fish species, but may capture only small numbers of fish species in demand for the live reef food fish trade (Hair *et al.*, 2002).

Feeds

Most marine finfish culture in Southeast Asia relies heavily on the use of small low-value or by-catch fish species, commonly termed 'trash fish'. This term is inaccurate in that these fish species would not necessarily otherwise be wasted. Alternative uses include reduction to fish sauce for human consumption, protein sources for other agricultural commodities (such as pigs and poultry) or even direct human consumption (New, 1996; Tacon and Barg, 1998; Edwards *et al.*, 2004). The availability of trash fish is often seasonal; for example, fishers may not be able to fish for these low-value species during rough weather. The low value of trash fish often means that they are poorly handled, and rancidity and vitamin degradation may lead to nutritional deficiencies in the fish to which they are fed. Feeding losses from trash fish are much higher than those from pellet feeds, e.g. 20–38% for trash fish versus 10% for pellet feeds used in salmonid culture (Wu, 1995; Phillips, 1998). Because of these losses, trash fish used as feed increases local pollution in the vicinity of the cages. The use of trash fish may also assist the spread of fish diseases.

There is an increasing trend towards the use of pelleted compounded diets for marine finfish culture. Although pellet diets still utilise comparatively high inputs of aquatic resources (typically 2–3 kg of fisheries product inputs for each 1 kg of cultured product) (Tacon and Barg, 1998) these are better than the typical input ratios for trash fish (usually 5:1–10:1). In addition, compounded diets provide an opportunity to replace fish protein sources with terrestrial protein such as meat and blood meals derived from abattoir by-products; in the case of grouper diets, up to 80% of fish meal can be replaced (Millamena and Golez, 2001; Millamena, 2002). There are now several companies producing specialised grouper diets, although the cost of these diets may be high because of relatively low demand compared with high-volume commodities such as milkfish and shrimp. The increasing demand for aquacultured groupers, the continuing demand for high quality product, and the problems of trash fish availability and quality, are driving the need to develop compounded diets for these species.

There are several constraints to the widespread use of compounded diets for grouper aquaculture:

- Farmer acceptance of pellet diets is often low because of the perception that these diets are much more expensive than trash fish. Farmers often do not appreciate that the food conversion ratios of pellet diets (usually 1.2–1.8:1) is dramatically better than that of trash fish (usually 5–10:1) and so the relative cost of pellet diets is often comparable, or lower than, the cost of trash fish required to produce the same biomass of fish.
- Lack of farmer experience in feeding pellets may result in considerable wastage.
- Fish fed on trash fish may not readily convert to a dry pellet diet, resulting in poor acceptance and perceived lack of appetite.
- Many rural areas have no storage facilities. This can result in degradation of the pellets, particularly vitamin content, resulting in poor growth and disease in fed fish.
- Variable product quality may also impact substantially on farmer acceptance of pellet diets.
- Small-scale fishers or farmers operating fish cages may not have access to the financial resources necessary to invest in purchase of pelleted diets or infrastructure such as refrigeration. Thus, they find it easier to collect trash fish themselves, or in small amounts as and when financial or trash fish resources are available.
- Distribution channels for pelleted feed are not widely available in rural areas. As well as limiting accessibility to the feed, this factor increases the cost of the feed.

Consequently, although many fish farmers are slowly changing to the use of compounded diets, trash fish will continue to be a major feed source for marine finfish aquaculture in the Asia–Pacific region for the foreseeable future.

Health management

The largely unregulated trade in aquatic organisms for aquaculture in the Asia–Pacific region is widely recognised as being responsible for the spread of aquatic animal pathogens within the region. Aquaculture of live reef food fish contributes to this trade through the movement of juvenile fish (both wild-caught and hatchery-reared) throughout the region (Bondad-Reantaso *et al.*, 2000), and, to a lesser extent, the movement of grown-out fish to local or international markets. Of specific concern in relation to groupers are the diseases viral nervous necrosis (VNN — also known as viral encephalopathy and retinopathy (VER)) and parasitic blood flukes (Bondad-Reantaso *et al.*, 2000). Measures are required to minimise spread of these and other serious diseases.

The 'Asia Regional Technical Guidelines on Health Management for the Responsible Movement of Live Aquatic Animals' provides guidelines for reducing risks associated with transboundary movements (FAO/NACA, 2000). A practical grouper health manual (APEC/SEAFDEC, 2001) provides guidance on hatchery and farm health management, and is available in English, Filipino, Indonesian, Thai, Mandarin and Vietnamese. The following points are a summary of the main health management measures for grouper aquaculture and trade (Bondad-Reantaso *et al.*, 2000):

- Hatchery health management. Hatcheries play a central role in supporting grouper aquaculture and are potential sources of diseases. Health screening, certification programs, hatchery health management and development of specific pathogen-free stocks are needed to reduce risks.
- On-farm health management. Risks of acute and chronic disease losses on farms can be controlled mainly through maintaining environmental quality, minimising stress to fish, routine monitoring of stock, and ensuring proper quarantine measures are applied when introducing new stock to the farm. Preventative methods should be applied; prophylactic use of antibiotics should be avoided and approved chemicals used only when absolutely necessary.
- Vaccines and vaccination. Fish vaccination has been proven as a cost-effective method of controlling certain infectious diseases of farmed fish in other regions of the world (Vinitnantharat, 2001) and in future may provide a basis for control of some grouper diseases.
- Disease monitoring and surveillance programs. National and regional disease surveillance and reporting systems (FAO/NACA, 2000) provide information required for making decisions on risks associated with movements, development of disease free zones where free movement can occur and responses to disease outbreaks.
- Diagnostic support. Proper diagnostic support through private or government laboratories is required for effective management interventions and disease control.

Environmental impacts

Marine fish aquaculture interacts with the coastal environment in several ways. Environmental changes occurring in some coastal areas caused by non-aquaculture uses have an influence on the success of marine cage culture. The discharge of nutrients in coastal waters has been blamed for the increased incidence of red tides, which have caused heavy economic losses to fish cage farms in some countries, most recently in Hong Kong Special Administrative Region during 1998 (Lai, 2002a).

Environmental impacts associated with marine finfish cage aquaculture derive mainly from nutrient inputs from uneaten fish feed and fish wastes (Phillips, 1998). For example, studies carried out in Hong Kong indicate that 85% of phosphorus, 80–88% of carbon and 52–95% of nitrogen inputs (from trash fish) to marine finfish cages may be lost through uneaten food, faecal and urinary wastes (Wu, 1995). These nutrient inputs, although small in comparison with other coastal discharges, may lead to localised water quality degradation and sediment accumulation. In severe cases, this 'self-pollution' can lead to cage farms exceeding the capacity of the local environment to provide inputs (such as dissolved oxygen) and assimilate wastes, contributing to fish disease outbreaks and undermining sustainability.

As noted earlier, the adoption of dry pellets rather than wet feeds reduces nutrient inputs through better feed utilisation. Other solutions to self-pollution of sea cage sites are to:

- ensure adoption of 'best or better management practices', including efficient feed formulation and feeding practices
- keep stocking densities and cage numbers within the carrying capacity of the local environment
- minimise and use chemicals responsibly
- ensure adequate water depth below cages and sufficient water movement to disperse wastes (Phillips, 1998).

There is increasing appreciation of the environmental impacts of marine finfish aquaculture in Southeast Asia, partly because of the worldwide focus on the environmental impacts of Atlantic salmon farming, and unregulated shrimp aquaculture. However, in most countries there is a lack of legislative frameworks and enforcement. Problems can be addressed by more emphasis on local planning initiatives and co-management frameworks, and zoning of coastal areas for marine fish farming. Hong Kong provides one example where the government has designated marine fish farming zones, however critics argue that zoning has allowed too much crowding and localised water pollution (Lai, 2002b; Sadovy and Lau, 2002). Therefore, zoning of marine fish farming areas has to be accompanied by control measures that limit farm numbers (or fish output, or feed inputs) to ensure effluent loads remain within the capacity of the environment to assimilate wastes (Phillips, 1998).

Increasing market demand for groupers with assured quality (and food safety), produced using environmentally sound farming practices, will provide further incentives for farmers to adopt improved environmental management practices for grouper aquaculture. A voluntary set of standards is being prepared for the Asia–Pacific region that, if adopted by aquaculture farmers and the live reef fish trade, would support wider adoption of better environmental management practices in grouper farming.

Economic and socio-economic aspects of grouper aquaculture

Marine finfish aquaculture provides important socio-economic benefits to coastal communities throughout the Asia–Pacific region. Although data are patchy, there is sufficient information available from several studies to indicate the importance of marine finfish aquaculture as an economic activity in coastal areas of Asia.

Indonesia

The development of backyard hatcheries in northern Bali has contributed substantially to the economic development of this region. A socio-economic assessment of marine finfish hatcheries in Bali, (Siar *et al.*, 2002) showed that these hatcheries are extremely profitable:

- Annual return (profit): A$6312 to AU$100,037
- Internal Rate of Return (IRR): 12% to 356%
- Benefit cost ratio: 1.27:1 to 3.09:1
- Payback period: 7 farms had a payback period of 1 year; only 1 farm had a payback period exceeding 10 years.One reason for the large-scale adoption of backyard hatcheries is the substantial increase in income that Indonesian farmers can obtain from fish culture compared with more traditional agricultural pursuits such as coconut plantations (Siar *et al.*, 2002).

Taiwan

Su (2005) gives the cost of production of *E. lanceolatus* fingerlings in Taiwan as US$186.88/1000 fish and the sale price as US$698.53/1000 fish. She describes the profit margins from breeding *E. lanceolatus* as 'lucrative'. In comparison, the cost of production of *E. coioides* is US$80.47/1000 fish and the sale price is US$117.64/1000 fish (Table 6). Miao and Tang (2002) give the 1999 cost of grouper (identified as *E. malabaricus*, but most likely *E. coioides*) fingerlings as 20–32 Taiwanese dollars (TWD) (US$0.63–1.00).

Table 6. Production, production costs and sale prices of *E. coioides* fry from Taiwanese indoor hatcheries.

	1987	1994	1999	2002	2003
Hatchery production capacity (tonnes)	–	700	–	300	300
No. of fry produced	–	119 000	–	350 000	250 000
Production cost of fry/1 000 pcs. (US$)	–	$321.80	–	$65.88	$80.47
Fry price/1000 pcs. (US$)	$3000	$676.47	$630–1000	$117.64	$117.64

Data from Su (2005) for 1994, 2002 and 2003; and from Miao and Tang (2002) for 1987 and 1999.

Since 1994 the cost of production for *E. coioides* fingerlings has decreased substantially from US$0.32 each in 1994 to US$0.07–0.08 in 2002 and 2003 (Table 9). This decrease in production cost has been associated with a decrease in the cost of eggs (Table 7). Similarly, the price of *E. lanceolatus* eggs in Taiwan has decreased from US$1750/kg to US $875/kg (Kao, 2004).

Table 7. Breakdown of fingerling production costs (% of total production cost) from Taiwanese indoor hatcheries.

	1994	2002	2003
Egg	35%	4%	5%
Feed	16%	27%	15%
Salaries	37%	46%	53%
Electricity	3%	5%	5%
Rentals	9%	18%	20%
Other	–	1%	1%

Source: (Su, 2005).

Philippines

Pomeroy *et al.* (2004) estimated the production cost of *E. coioides* and *E. malabaricus* fingerlings in the Philippines at US$0.23 each. This is comparable to the 1994 fingerling production cost for Taiwan (Su, 2005). This cost reflects the relatively undeveloped nature of the hatchery technology for these species in the Philippines, compared with current production in Taiwan. In comparison, wild-caught fry (6 cm TL) in the Philippines sell for US$0.36–0.50 (Pomeroy *et al.*, 2004).

A major issue in regard to socio-economic benefits from aquaculture is the ability of the poor to access and benefit from this technology (Haylor *et al.*, 2003). Hatcheries, in particular, require substantial capital investment and training. They may be less accessible to poor people because of the limited availability, and high repayments costs, of capital (Haylor *et al.*, 2003). Pomeroy *et al.* (2004) undertook economic analyses of grouper broodstock maintenance, hatchery/nursery, and grow-out operations, plus a combined broodstock/hatchery/nursery/grow-out system for the

Philippines. They concluded that all four systems are financially feasible, but access to the high capital requirement for broodstock, hatchery and integrated systems would put these beyond the reach of many small producers. They estimated the costs for a broodstock and nursery/hatchery system at US$68,400 and for an integrated system at US$98,970 (Pomeroy *et al.*, 2004). However, Siar *et al.* (2002) found that capital requirements for small-scale backyard hatcheries in Indonesia could be as low as US$4700 (1 unit, or 2 larval rearing tanks), making this technology relatively affordable to poor people in coastal areas.

In Bali, it is the larger hatcheries (often supported by Javanese or Chinese investment) that have the greater capacity to culture high value groupers, due to their ability to diversify their operations and absorb the higher risk that is inherent in culturing these species (Siar *et al.* 2002). The smaller hatcheries tend to concentrate on milkfish culture which, although less profitable, is also less risky (Siar *et al.* 2002).

In contrast to hatcheries, grow-out operations require considerably less capital: US$1470, excluding the cost of fish transport boxes, to produce 1.4 tonnes p.a. (Pomeroy *et al.*, 2004). However, operating costs, particularly for feed, are much higher for grow-out farms.

Evaluations of the profitability of grouper culture in the Philippines by the Southeast Asian Fisheries Development Centre's Aquaculture Department (SEAFDEC AQD) have shown that grouper culture in both ponds and in coastal cages is highly profitable (Table 8) with high return on investment and short payback periods (Baliao *et al.*, 1998; Baliao *et al.*, 2000).

Table 8. Estimated profitability of grouper (*E. coioides*) grow-out in ponds and in cages in the Philippines.

	Ponds (0.9 ha)	Cages (6 × 75 m^3)
Annual income	$9392	$11,631
Net profit	$6105	$4278
Break-even volume	–	684 kg
Break-even selling price	–	$6.80
Return on investment	82%	59%
Payback	1.22 years	1.68 years

(Baliao *et al.*, 1998; Baliao *et al.*, 2000).

Similarly, Pomeroy *et al.* (2004) found that economic analysis of grouper (*E. coioides*/ *E. malabaricus*) grow-out operations in the Philippines indicated that they were profitable, generating a net income of US$9600 p.a. for a 1.4 tonne p.a. farm.

Yap (2002) notes that cage aquaculture of high-value species such as groupers is particularly attractive to poor farmers in the Philippines. Yap (2002) explains that: 'This is because grouper can yield a profit margin of as much as US$2.50 per kg as against only US$0.15 to $0.20/kg for milkfish. To earn US$1000 one only has to raise 400 kg of grouper as against at least 5000 kg of milkfish. With an operating capital requirement of US$3.00 per kg for grouper and US$0.80 for milkfish it would take US$1200 to raise the 400 kg of grouper as against US$4000 for the 5000 kg of milkfish'.

Priorities for marketing of aquaculture marine finfish

As noted above, the rapid development of grouper aquaculture in the Asia–Pacific region is driven by market demand for high-value live reef food fish. Consequently, information on market trends is vital to support the continuing development of this sector. At the 'Development of Sustainable

Marine Finfish Aquaculture in the Asia–Pacific Region' workshop held in HaLong City, Vietnam, 30 September–4 October 2002, a needs evaluation was undertaken to identify research, development and extension needs to support the continued development of sustainable marine finfish aquaculture in the Asia–Pacific region. A full list of the priorities for the various sectors is provided in Rimmer *et al.* (2004), and those identified with regard to markets are listed in Table 9.

Table 9. Constraints/issues, required responses and priorities for marketing of live reef food fish.

Constraint/issues	Activities required	Priority (H/M/L)
► Certification, eco-labelling	► Voluntary codes of practice	M
► Better meeting market requirements.	► Market demand information. ► Forecasting.	H
► Need to improve market chain.	► Increase communication, interaction between producers and market end. ► Develop farmer cooperatives to improve bargaining power. ► Promote aquacultured fish as higher quality product, ciguatera free product.	H
► Lack of understanding/uncertainly on long-term market demand for marine finfish.	► Include market assessment for non-live fish markets.	
► Consumer perception regarding quality of aquaculture/wild product, esp. fat quality.	► Feeds development research to incorporate assessment of end-product quality (see grow-out).	
► Focus has been on high-value species.	► Need to focus on other species that are maricultured. ► Market study for full range of marine fish in Asia–Pacific region.	

Identified at the 'Development of Sustainable Marine Finfish Aquaculture in the Asia–Pacific Region' workshop, HaLong City, Vietnam, 30 September–4 October 2002 (from Rimmer *et al.*, 2004).

Participants identified a need to differentiate aquacultured and wild-caught product, and to promote aquacultured product as sustainably sourced, higher quality and ciguatera-free. The issue of market intelligence (market demand and price responses for live and dead fish markets) was also regarded as one of vital importance for fish farmers to enable them to business decisions on the basis of sound market information.

Future trends

Asia

Hatchery production of grouper fingerlings is increasing rapidly. The major producer countries are Taiwan and Indonesia with reported fingerling production of 21 and 5 million fingerlings respectively in 2004. Fingerling production in Taiwan is relatively stable at around 20–25 million grouper fingerlings per annum; fingerling production in Indonesia is increasing steadily and this trend is expected to continue in the immediate future. Development of hatcheries in other countries will further increase the availability of fingerlings throughout Asia.

The diversity of species produced in hatcheries is increasing. Recently, there has been increasing production of *E. fuscoguttatus* fingerlings from hatcheries in Indonesia and Taiwan, and *C. altivelis* from Indonesia. Taiwan continues to be a major fingerling producer and centre for diversification. Fingerlings of *E. lanceolatus* and *P. leopardus* are now available from Taiwan.

As fingerling production increases, and there is more competition amongst hatcheries, fingerling prices will continue to decrease. Since fingerling cost can be a major component of the production cost of aquacultured product, lower fingerling costs will reduce grow-out production costs.

Increased fingerling availability and lower fingerling costs will drive increasing aquaculture production of groupers in Asia. This will lead to high volumes of some products. In the short-term, there will be substantial quantities of *E. fuscoguttatus* produced. In the longer term, there will be increasing production of several other species, including *E. lanceolatus* and *Plectropomus* species.

To give an indication of the extent of the potential increase in production from aquacultured groupers, we have conservatively estimated the likely production based on 2004 fingerling production data from Taiwan and Indonesia (Table 10). The data indicate a significant expansion of production of *E. lanceolatus* and *E. fuscoguttatus* in the short-term. Although the likely production of *C. altivelis* is relatively small (<200 tonnes), this production has potential to impact what is a relatively small market for this high-value species. Imports of *C. altivelis* into Hong Kong ranged from about 14 to 20 tonnes per annum from 1997 to 2000 (Lau and Parry-Jones, 1999; McGilvray and Chan, 2001). Similarly, records for imports of *E. fuscuguttatus* for 1999 and 2000 indicate that less than 500 tonnes per annum were imported into Hong Kong (McGilvray and Chan, 2001); whereas potential aquaculture production of this species in the short-term is at least 2700 tonnes (Table 10).

Table 10. Estimate of live reef food fish aquaculture production based on reported 2004 fingerling production in Taiwan and Indonesia.

Species	Fingerlings	Survival	Harvest size (kg)	Production (tonnes)
Taiwan				
E. coioides	8 700 000	35%	0.7	2132
E. lanceolatus	2 500 000	30%	2.0	1500
E. fuscoguttatus	9 100 000	30%	0.7	1911
P. leopardus	400 000	30%	0.5	60
Indonesia				
E. fuscoguttatus	3 800 700	30%	0.7	798
C. altivelis	1 050 420	25%	0.7	184

Fingerling production data are from Sugama (2003; and *pers. comm.*, 2005) and Su (2005). Survival estimates assume deformity rates (discards) of 30% for *E. coioides*, 50% for *C. altivelis*, 40% for other species; and 50% survival of non-deformed fish to harvest size.

In response to increased production and the expected decrease in price, grouper farmers will have to become more efficient by increasing the intensity of production and reducing input costs. Given that the major input cost for grouper aquaculture in Asia is feed, feeds and feeding strategies will need to become more cost effective. The impacts of increased production of marine finfish, including groupers, in Asia will lead to a range of follow-on effects, including:

- increased demand for fishery products (trash fish) to feed to marine finfish
- increased disease prevalence and outbreaks of previously unrecognised or unreported diseases as culture intensity increases
- environmental impacts of unregulated cage culture development (local pollution, fish health issues due to poor water quality, etc.).

In response to these issues, many countries in Asia are developing management techniques and processes to deal with the rapid expansion of marine finfish aquaculture. The major focus remains on feeds (particularly the heavy reliance on trash fish) and disease control.

Pacific

Most Pacific countries have an inadequate technology base for marine finfish aquaculture. Fingerlings of high-value species are generally not available. Methods to collect pre-settlement juveniles have had mixed results, but generally provide aquarium species rather than food fish species.

Hatchery production of juvenile marine finfish could be undertaken in some Pacific countries where there is an adequate technology base, such as New Caledonia and Fiji. New Caledonia is currently developing a 'country laboratory' near Kone in the North Province, to produce fingerlings of high-value marine finfish for aquaculture (A. Rivaton, *pers. comm.*).

Pacific countries should resist the temptation to import fingerlings from Asia, with the inherent risks of disease and introduced species translocations. A useful model for the Pacific would be the development of a relatively centralised hatchery production sector (in, say, New Caledonia or Fiji) that produced fingerlings for distribution to other countries for grow-out. However, stringent health management procedures and quarantine would need to be implemented as part of such a development.

Another restriction to the development of marine finfish aquaculture in the Pacific is the availability of feeds. Trash fish resources are limited (compared with Asia) and the use of farm-made or compounded commercial feeds would be essential to support marine finfish aquaculture. Many countries have substantial supplies of tuna waste that could be utilised in compounded feeds. However, the aquafeeds industry in the Pacific is in its infancy.

An important restriction to the development of marine finfish aquaculture in the Pacific is access to markets. There are limited flights to Asia, and limited freight capacity. Most Pacific airlines operate smaller aircraft such as the Boeing 737 series that will not take the larger live transport bins used to ship live groupers to Hong Kong from Australia and other source countries. This severely limits the capacity to airfreight product from the Pacific to Asia.

An alternative is surface vessel transport of live fish products to Asia. However, because of the length of the journey from Hong Kong to the Pacific, live fish boats need to pick up a large volume of fish each trip (>10 tonnes) to maintain profitability. The provision of regular quantities of live fish based on this model would require either large-scale commercial aquaculture, or some type of centralised purchasing/distribution system in the Pacific.

Generally, the long distances to market and consequent high freight costs and the limited transport infrastructure will provide a competitive disadvantage for marine finfish aquaculture for the live reef food fish trade in the Pacific compared with Asia.

Further information

The Asia–Pacific Marine Finfish Aquaculture Network publishes a fortnightly e-newsletter and a quarterly e-magazine that provides updated information on the status of marine finfish aquaculture in the Asia–Pacific region, particularly high-value species in demand in the live reef food fish trade. The web site provides weekly data on live fish prices from Hong Kong and southern China (Huangsha). For further details, see www.enaca.org/marinefish.

References

APEC/SEAFDEC 2001. Husbandry and health management of grouper. Asia–Pacific Economic Cooperation (APEC), Singapore, and South-east Asian Fisheries Development Centre (SEAFDEC), Iloilo, Philippines.

Awang A.B. 2002. Status of marine finfish aquaculture in Malaysia. In: Paper presented to the Workshop on Sustainable Marine Finfish Aquaculture in the Asia–Pacific Region, HaLong City, Vietnam, 30 September–3 October 2002.

Baliao D.D., de los Santos M.A., Franco N.M. and Jamon N.R.S. 2000. Grouper culture in floating net cages. Aquaculture Department, Southeast Asian Fisheries Development Center, Tigbauan, Iloilo, Philippines.

Baliao D.D., de los Santos M.A., Rodriguez E.M. and Ticar R.B. 1998. Grouper culture in brackishwater ponds. Aquaculture Department, Southeast Asian Fisheries Development Center, Tigbauan, Iloilo, Philippines.

Bondad-Reantaso M.G., Humphrey J., Kanchanakhan S. and Chinabu S. 2000. Development of a regional research programme on grouper virus transmission and vaccine development (APEC FWG 02/2000). Report of a workshop held in Bangkok, Thailand, 18–20 October 2000. Asia–Pacific Economic Cooperation, Fish Health Section of the Asian Fisheries Society, Aquatic Animal Health Research Institute, Network of Aquaculture Centres in Asia–Pacific, Bangkok, Thailand.

Doherty P.J. 1991. Spatial and temporal patterns in recruitment In: The ecology of fishes on coral reefs (Sale P.F. ed.), pp. 261–293. Academic Press, San Diego.

Dufour V. 2002. Reef fish post-larvae collection and rearing programme for the aquarium market. Live Reef Fish Information Bulletin, 10: 31–32.

Edwards P., Tuan L.A. and Allan G.L. 2004. A survey of marine trash fish and fish meal as aquaculture feed ingredients in Vietnam. ACIAR Working Paper No. 57. Australian Centre for International Agricultural Research, Canberra.

Estudillo C.B. and Duray M.N. 2003. Transport of hatchery-reared and wild grouper larvae, Epinephelus sp. Aquaculture, 219: 279–290.

FAO. 2005. FAO yearbook, Fishery statistics, Aquaculture production 2003. Vol 96/2. Food and Agriculture Organisation of the United Nations (FAO), Rome.

FAO/NACA. 2000. Asia Regional Technical Guidelines on Health Management for the Responsible Movement of Live Aquatic Animals and the Beijing Consensus and Implementation Strategy. FAO Technical Paper No. 402. Food and Agriculture Organisation of the United Nations, Rome.

Hair C., Bell J. and Doherty P. 2002. The use of wild-caught juveniles in coastal aquaculture and its application to coral reef fishes In: Responsible marine aquaculture (Stickney R.R. and McVey J.P. eds.), pp. 327–353. CAB International.

Haylor G., Briggs M.R.P., Pet-Soede L., Tung H., Yen N.T.H., O'Callaghan B., Gow C., DeVantier L., Cheung C., Santos R., Pador E., de la Torre M., Bulcock P. and Savage W. 2003. Improving Coastal Livelihoods Through Sustainable Aquaculture Practices: A Report to the Collaborative APEC Grouper Research and Development Network (FWG/01/2001). STREAM Initiative, NACA, Bangkok, pp. 37.

Henry M. 2005. Live reef food fish trade — Federated States of Micronesia. In: SPC/ACIAR Workshop on Economics and Market Analysis of the Live Reef Food Fish Trade in Asia-Pacific, Noumea, New Caledonia, 2–4 March 2005.

Johannes R.E. and Ogburn N.J. 1999. Collecting grouper seed for aquaculture in the Philippines. Live Reef Fish Information Bulletin, 6: 35–48.

Kao C.C. 2004. Development of grouper culture in Taiwan — a solution to reduce destructive fishing practices in coral reefs. Infofish International 3/2004, 24–28.

Lai L.W.C. 2002a. Marine fishing and fish culture in Hong Kong: a note on the property rights and regulatory frameworks. Aquaculture Economics and Management, 6: 153–165.

Lai L.W.C. 2002b. An overview of research on aquaculture economics and management in Hong Kong. Aquaculture Economics and Management, 6: 131–152.

Lau P.F. and Li L.W.H. 2000. Identification guide to fishes in the live seafood trade of the Asia–Pacific region. World Wide Fund for Nature, Hong Kong, and Agriculture, Fisheries and Conservation Department, Hong Kong, Hong Kong.

Lau P.F. and Parry-Jones R. 1999. The Hong Kong trade in live reef fish for food. TRAFFIC East Asia and World Wide Fund for Nature Hong Kong, Hong Kong.

Lay U.K.K. 2002. Status of marine finfish aquaculture in Myanmar. In: Paper presented to the Workshop on Sustainable Marine Finfish Aquaculture in the Asia–Pacific Region, HaLong City, Vietnam, 30 September–3 October 2002.

Le T.L. 2002. Status of marine finfish aquaculture in Vietnam. In: Paper presented to the Workshop on Sustainable Marine Finfish Aquaculture in the Asia–Pacific Region, HaLong City, Vietnam, 30 September–3 October 2002.

Liao I.C., Su H.M. and Chang E.Y. 2001. Techniques in finfish larviculture in Taiwan. Aquaculture, 200: 1–31.

Liao I.C., Su M.S. and Chang S.L. 1994. A review of the nursery and grow-out techniques of high-value marine finfishes in Taiwan. In: Culture of high-value marine fishes in Asia and the United States (Main K.L. and Rosenfield C. eds.), pp. 121–137. The Oceanic Institute, Hawai, USA.

McGilvray F. and Chan T.T.C. 2001. The trade in live reef food fish: A Hong Kong perspective. International Marine Life Alliance, Hong Kong.

Miao S. and Tang H. 2002. Bioeconomic analysis of improving management productivity regarding grouper Epinephelus malabaricus farming in Taiwan. Aquaculture 211: 151–169.

Millamena O.M. 2002. Replacement of fish meal by animal by-product meals in a practical diet for grow-out culture of grouper Epinephelus coioides. Aquaculture, 204: 75–84.

Millamena O.M. and Golez N.V. 2001. Evaluation of processed meat solubles as replacement for fish meal in diet for juvenile grouper Epinephelus coioides (Hamilton). Aquaculture Research, 32: 281–287.

New M.B. 1996. Responsible use of aquaculture feeds. Aquaculture Asia, 1: 3–15.

Phillips M.J. 1998. Chapter 2 —Tropical mariculture and coastal environmental integrity. In: Tropical Mariculture (De Silva S.S., ed.), pp. 17–69. Academic Press, London.

Pomeroy R.S., Agbayani R., Duray M., Toledo J. and Quinito G. 2004. The financial feasibility of small-scale grouper aquaculture in the Philippines. Aquaculture Economics and Management, 8: 61–83.

Rimmer M. 1998. Grouper and snapper aquaculture in Taiwan. Austasia Aquaculture, 12: 3–7.

Rimmer M.A., McBride S. and Williams K.C. 2004. Advances in grouper aquaculture. ACIAR Monograph 110. Australian Centre for International Agricultural Research, Canberra.

Rimmer M.A., Williams K.C. and Phillips M.J. 2000. Proceedings of the Grouper Aquaculture Workshop held in Bangkok, Thailand, 7–8 April 1998. Network of Aquaculture Centres in Asia–Pacific, Bangkok, Thailand.

Sadovy Y. 2000. Regional survey of fry/fingerling supply and current practices for grouper mariculture: evaluating current status and long-term prospects for grouper mariculture in Southeast Asia, pp. 120. University of Hong Kong, Hong Kong SAR, China.

Sadovy Y. 2005. Humphead wrasse listed on CITES. Live Reef Fish Information Bulletin, 13: 42–43.

Sadovy Y. and Pet J. 1998. Wild collection of juveniles for grouper mariculture: just another capture fishery? Live Reef Fish Information Bulletin, 4: 36–39.

Sadovy Y.J. and Lau P.P.F. 2002. Prospects and problems for mariculture in Hong Kong associated with wild-caught seed and feed. Aquaculture Economics and Management, 6: 177–190.

Siar S.V., Johnston W.L. and Sim S.Y. 2002. Study on economics and socio-economics of small-scale marine fish hatcheries and nurseries, with special reference to grouper systems in Bali, Indonesia. 36 pp. Report prepared under APEC Project FWG 01/2001 — 'Collaborative APEC Grouper Research and Development Network'. Asia–Pacific Marine Finfish Aquaculture Network Publication 2/2002. Network of Aquaculture Centres in Asia–Pacific, Bangkok, Thailand.

Su H.M. 2005. Marine fish hatchery production — the Taiwan model. Aquaculture Asia–Pacific, 1: 24–26.

Sugama K. 2003. Indonesia focuses on groupers. Asian Aquaculture Magazine September–October 2003, 14–15.

Tacon A.G.J. and Barg U.C. 1998. Chapter 6 — Major challenges to feed development for marine and diadromous finfish and crustacean species. In: Tropical Mariculture (De Silva S.S., ed.), pp. 171–207. Academic Press, London.

Vinitnantharat S. 2001. Immunological methods of disease control. In: Report and proceeding of APEC FWG 02/2000 'Development of a Regional Research Programme on Grouper Virus Transmission and Vaccine Development', 18–20 October 2000, Bangkok, Thailand. (Bondad-Reantaso M.G., *et al.*, eds.), pp. 103–109. Asia Pacific Economic Cooperation (APEC), Aquatic Animal Health Research Institute (AAHRI), Fish Health Section of the Asian Fisheries Society (FHS/AFS) and the Network of Aquaculture Centres in Asia–Pacific (NACA). Bangkok, Thailand.

Watson M., Power R., Simpson S. and Munro J.L. 2002. Low cost light traps for coral reef fishery research and sustainable ornamental fisheries. Naga, the ICLARM Quarterly, 25: 4–7.

Wu R. 1995. The environmental impact of marine fish culture: towards a sustainable future. Marine Pollution Bulletin, 31: 159–166.

Yap W.G. 2002. Role of mariculture in securing food supply and reducing poverty in the Philippines. In: World Aquaculture 2002 International Aquaculture Conference and Exposition, pp. 864. World Aquaculture Society, Beijing, China.

13. Market chain analysis for the trade in live reef food fish

Geoffrey Muldoon[1]

Introduction

For most seafood products there are usually numerous intermediaries along the market, or valuechain between the primary producer (fisher) and the consumer. Market chain analysis in the resource sector has historically been undertaken in the agricultural sector with information provided on profitability and margins experienced by the various intermediaries, hereinafter referred to as agents, along the market chain (Kaplinsky, 2000; Fitter and Kaplinsky, 2001, Stevens, 2001). More recently, considerable research has been undertaken on price and margin relationships and transmission of price variability along European seafood chains, specifically cod and salmon (Asche *et al.*, 1998; Hartmann *et al.*, 2000; Gonzales *et al.* 2002; Guillotreau, 2003).

We have been able to find no such studies dealing with tropical fisheries of the Asia–Pacific region with the exception of Jacinto (2004) who describes a research framework for value chain analysis in small-scale fisheries in the Philippines. This paucity of research on tropical fisheries is likely to be a result of data limitations in these fisheries due to the geographic remoteness of fishing grounds, the large number of landing sites, the range of fishing gears and limited monitoring and enforcement capacity of governments (Christensen and Pauly, 1998; Pauly, 1998).

This paper is part of a larger project that aims to analyse economic and market impacts of the live reef food fish (LRFF) trade in Asia–Pacific. The project is funded by the Australian Centre for International Agricultural Research (ACIAR). Outcomes from this paper, along with related project components examining supply and demand, will contribute to the development of a partial equilibrium model of the LRFF trade. This paper aims to identify and measure the key cost and revenue components in the product marketing chain and to incorporate risk factors into market chain models by considering, identifying and measuring the:

(a) relative size and distribution of value along the market chain

(b) risk borne by various agents

(c) price relationships and the transmission of price information along this chain.

The last of these most commonly relies on the use of co-integration analysis to delineate markets (Engle and Granger, 1987; Gordon *et al.,* 1993, Asche *et al.*, 1997). The application of these econometric techniques to this project will be hindered by the paucity and quality of data available for each intermediary level and the length of time over which these data extend.

For (a) and (b) above, primary and secondary data will be used to develop models of the market chain from the point of capture to the point of sale. These models will aid managers of capture fisheries and the aquaculture sector to assess the future viability of the fisheries under their jurisdiction.

The paper proceeds as follows: Section 2 provides a background to market chains. Section 3 provides a background to LRFF trade in supply and demand countries in the context of the market chain, including its extent and a descriptive overview of agents along the chain. Section 4 presents empirical data on prices, costs incurred (e.g. freight, processing) and revenues along the LRFF chain of custody. Section 5 is a brief discussion of the theory of price and margin

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relationships and transmission of price variability in the context of characteristics and nature of the trade that limit the application of these econometric techniques. The final section discusses these empirical data in the context of technological and infrastructural improvements that could precipitate the geographic expansion of the trade, or lead to greater volumes being traded.

The market chain

The terms market chain and economic value chain are considered interchangeable for the purpose of this paper. A 'value chain' is a description of the full range of activities required to bring a product through different stages of production, through to delivery to consumers, and then disposal (Kaplinsky and Morris, 2003). Market chain analysis aims to provide information on profitability for the various agents along the market chain (Ferris *et al.*, 2001). Economic value chain analysis describes the range of activities required to bring a product to the final consumer and, in the case of international products, the extent to which intermediaries/agents gain from participating in the chain (Jacinto, 2004). A traditional food industry value chain consists of the producer, processor, wholesaler, exporter, importer, retailer and consumer.

In fisheries such as the LRFF trade, where unsustainable fishing practices are in use, international trade can pose significant risks to valuable ecosystems and social and economic sustainability (Sadovy and Vincent, 2002; Sadovy *et al.*, 2004). Paradoxically, high-value fisheries such as the LRFF trade offer a potential source of much needed income for local fishing communities. Market chain analysis can help to identify constraints (e.g. information flows), inequities (distribution of value) and practices (e.g. handling, quality control) along the chain that can serve to enhance benefits of trade to agents, especially those in source countries.

A number of factors determine the percentage of the final value extracted at certain points along the market chain, in particular market chain complexity and risk. Complexity refers to the collective number of agents in the supply chain in exporting and importing countries (MacFadyen *et al.*, 2003). The complexity of the market chain may expand or contract depending on the country of product origin, market sophistication/maturity and the distance of fishing grounds (i.e. fisher) from major infrastructure (storage and transport facilities). Remoteness, along with handling and husbandry techniques, will also dictate the risk of product loss faced by the various agents. (See Sadovy and Vincent (2002) for a discussion about poor handling and husbandry practices.) Other factors that influence distribution of value include: (a) the amount of processing required to prepare a product for consumer markets; (b) storage and transportation requirements of the product; and (c) the perishable nature of the product.

Profit margins may show a steady increase moving downstream along the chain from fisher to retailer, or they may be haphazardly distributed along the chain.

More processing results in a greater percentage of the final value accruing to processors: usually at the expense of the raw material supplier (fisher). Where the product is transported in fresh or frozen form, a greater contribution of final value tends to accrue to wholesalers and distributors. Finally, where the product is perishable in nature, as with LRFF, the value extracted by retailers is greater. As an example, a value chain for unprocessed protein might generate 25% for retailers, 25% for wholesalers/distributors, leaving 50% for producers. Alternatively, the value chain for processed products would provide 40% for retailers, 35% for wholesalers/distributors, and 5% for processors leaving 20% for producers (Wolfe, 2002).

There is a paucity of literature about, and limited empirical data on, product market chains, profit margins and the distribution of value along chains in developing countries. Supply

chains for marine ornamental fish export trade in the Philippines and Indonesia have been examined (Wood, 2001; MacFadyen *et al.,* 2003). The Food and Agriculture Organisation (FAO) (van Anrooy, 2003) examined cooperation and market performance for finfish aquaculture in Vietnam, while Jacinto (2004) presented a research framework for value chain analysis for small-scale Philippines fisheries. Some of the key elements identified in these case studies are discussed in the following sections.

Pricing and price transmission

The number of agents and market structures at each stage of the chain can affect the transmission of information about demand, and hence price, along the chain. Moreover, the difference between prices received by fishers and prices paid by consumers tends to increase the more agents (middlemen) in the market chain (MacFadyen *et al.*, 2003). A lack of transparency in price setting and limited access to market and price information, especially at the primary producer level, is one of the main causes of price inequity. Also, the oligopolistic nature of markets at the buyer (middlemen, wholesaler/exporter) level of the market chain raises the possibility for price collusion (van Anrooy, 2003). Oligopolistic markets are those that have few buyers with one or more buyers able to influence the market and other buyers.

Agents will respond uniquely to changes in relative prices. In general, changes in consumer demand can be gradually distorted down the chain so that derived demand for the seafood differs substantially from consumer demand (Asche *et al.*, 1998). For this project, the issue is whether price changes are being transmitted along the market chain and, if so, how various agents along the chain might respond to price changes. For example, are fishers varying their effort in response to price, or are their effort levels consistent regardless of price changes with the principal outcome of price changes being the increased margins received by downstream agents along the chain?

Distribution of value and risk

The distribution of value of marine products is recognised as an issue of great concern in developing country export fisheries, both in terms of the percentage of final value accruing to agents along the chain and the under-pricing of resources. Final consumer prices should reflect true costs of fish catches in terms of externality costs imposed on communities from overexploitation of their resources (Jacinto, 2004). Even so, profit margins and value need to be considered in the context of risk borne by the respective agents along the market chain.

In the case of wild-caught fisheries it has been suggested that fishers are usually poorly paid based on the final value of seafood products (Wood, 2001). However several factors would give explanation for their receiving a relatively smaller percentage of final value. The remoteness of fishing grounds and small individual catches requires middlemen who can consolidate catches into sufficient quantities for export and direct collector efforts to meet exporter needs. Often these middlemen provide credit to fishers in the form of gear etc. to facilitate their fishing activities, although credit arrangements are usually not 'mutually beneficial'.

For export fisheries, financial risks increase as the product moves along the market chain. The middlemen bear the costs of holding fish post-harvest. The costs of transportation to markets are borne by middlemen, wholesalers and exporters and/or importers. Shipping and freight costs can make up between 50–66% of landed price paid by importer, while at the consumption end of the chain, retailers incur considerable costs (e.g. rent, wages) (MacFadyen *et al.*, 2003). The greater

downstream risks of financial losses from mortality, prior to the product reaching consumer markets, partly explains the inequitable distribution of value.

For aquaculture fisheries it has been shown that processors receive larger absolute returns while the aquaculture farmers recieve the largest relative returns of the agents along the market chain. Margins for wholesalers and retailers appear constant over time (van Anrooy, 2003). Margins in the ornamental trade tend to be fixed at all stages of the market chain above collector level.

Market structures in developing fisheries with complex market chains tend to be fixed such that reducing links in the market chain to benefit small-scale fishers is unlikely to be possible (MacFadyen *et al.*, 2003). Also, governance and distributional outcomes are often skewed toward agents, such as wholesalers and exporters, thereby marginalising small-scale fishers. Horizontal integration, where adjacent communities or aquaculture farms form cooperatives, could enhance bargaining power and lead to improved returns.

While horizontal cooperation at various stages along the chain does occur, economic relations in a fishery product chain are generally vertical. Vertical cooperation is essential in fishery chains because of perishability of the product, variations in product quantity and quality, consumer awareness of product quality and food health issues, and differences in economies of scale that constrain vertical integration. These issues highlight the need for improved flow of, and increased access to, market information, and to better storage and transport practices along the product chain (van Anrooy, 2003).

The key objectives of vertical cooperation in the market chain are generating larger profits for cooperatives through increased market share, improved product quality and product branding. An example of this is the higher price paid for Australian fish entering the LRFF trade because of their quality. Opportunities for vertical cooperation are likely to be greater in controlled environments such as finfish aquaculture where benefits are easier to generate due to the ability of supply to meet: variant demand conditions, increased access to product quality information, easier implementation of quality control activities, and increased access to credit (van Anrooy, 2003).

The market chain for live reef foodfish

The market for live fish is longstanding in Southeast Asia, although the LRFF trade first began in the mid 1970s. The demand for LRFF is concentrated in Hong Kong and China with more than 20 countries in Southeast Asia and the Pacific supplying fish to this market. As the traditional sources of LRFF in the South China Sea began to show signs of over-exploitation, the trade expanded into new areas; firstly in Southeast Asia and more recently the Indo-west Pacific (Sadovy *et al.*, 2004) (Figure 1).

As a high value commodity there is a perceived potential for high economic gains along the chain. Indeed, the high price of LRFF in Hong Kong has created an impression among suppliers in importing countries that the price they receive from buyers one step along in the chain is too low (Chan, 2001). However, in this extended market chain for LRFF, each agent requires an acceptable margin to continue trading. In practice these gains tend to be unevenly distributed among agents for a variety of reasons including: fishers' lack of knowledge of final values; high transport costs incurred by traders when shipping fish across large distances either by sea or air; the high risks of mortality endured by traders during transport; health scares (e.g. ciguatera); and shocks in economic conditions (e.g. an outbreak of Severe Acute Respiratory Syndrome (SARS)).

The characteristics of the LRFF trade, such as its international scope, undeveloped storage and transport infrastructure, low technology of gear and the distances of source countries from

markets, have resulted in the market chain for LRFF becoming quite extended. For example, the costs of shipping a consignment of LRFF may cost in excess of one-quarter of million US dollars, an outlay unaffordable to retailers. The trade itself is complex with LRFF passing through many levels of trade between the fisher and the restaurant (Figure 2).

The market chain can be shorter in some countries than in others. In Southeast Asia, the supply side of the market chain includes one or two middlemen whose role is to consolidate catches from independent fishers into sufficient quantities for movement along the chain. There are no middlemen in Australia: fish are passed from fishing firms who employ fishers to wholesaler/exporters. The chain is historically shorter still in the Pacific with fishers being employed directly by exporters, who tranship almost entirely by sea.

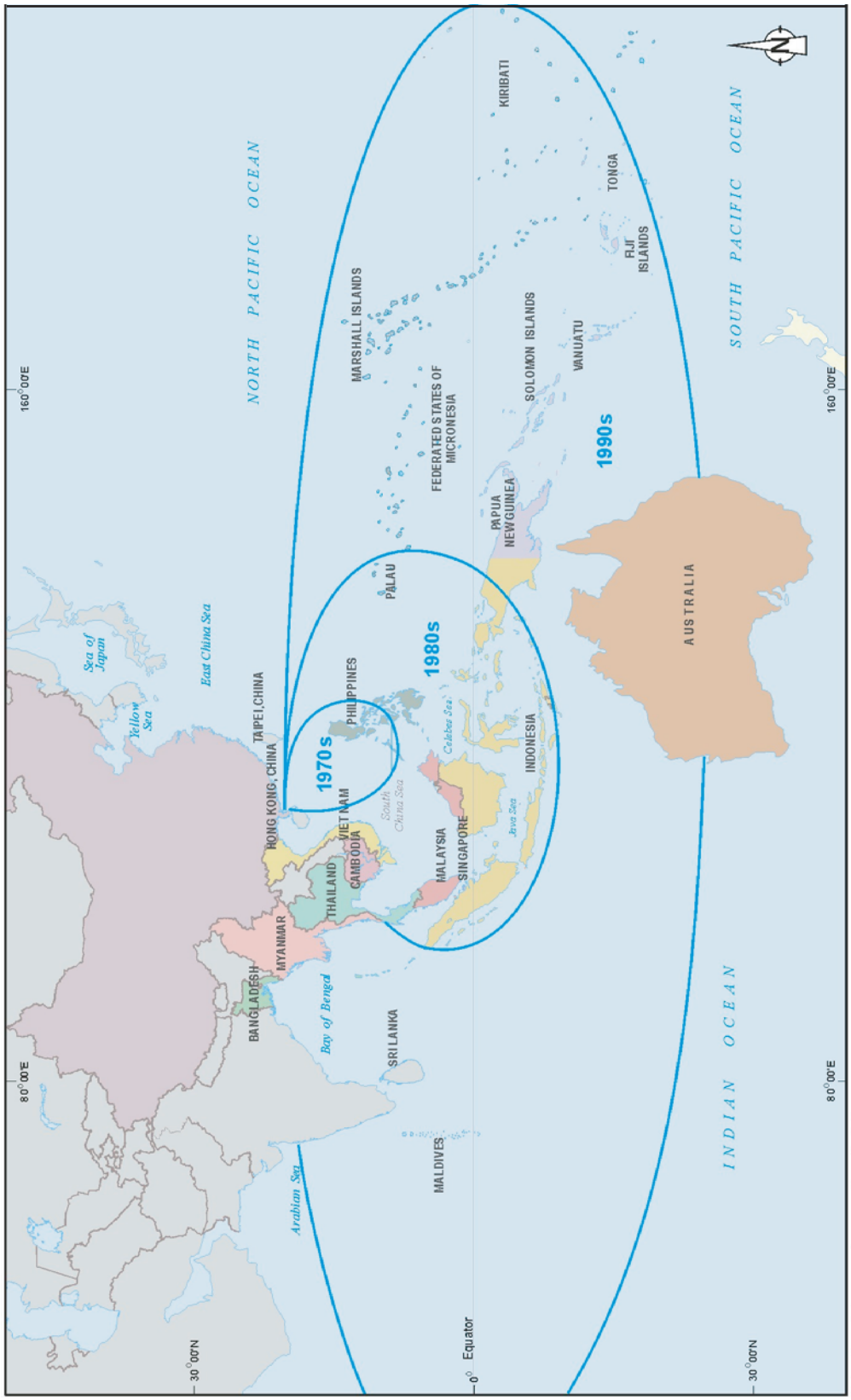
Traditionally there are diverging interests between upstream (fishers) and downstream (consumer) agents. Fishers seek the highest possible prices, while downstream agents (wholesalers, exporters, importers) are better able to integrate into organised marketing channels and contracts. The interests themselves are not diverging, everyone wants the highest price. It is the access to channels and contracts that seems to differ. This usually infers a greater market power by those intermediaries further down the chain. The predominantly artisanal and subsistence nature of fishermen in the LRFF trade, with the exception of those in Australia, tend to exacerbate this concentration of market power.

The market chain and operational costs for wild-caught live reef fish

Capital investment in fishing vessels and gear varies across countries. In Australia, capital costs range from US$100,000 to US$450,000 (Sadovy *et al.*, 2004). This contrasts with the average investment in the Philippines of US$700 for smaller operations, and up to US$2000 for larger boats capable of travelling farther and supporting more fishers (Padilla *et al.* 2003). Comparable investment costs and financial arrangements exist in Indonesia. Exporters and dealers usually extend financial assistance to fishers to enable such investment with repayments deducted directly from fishers' wages or catch revenue until the loan is repaid. During difficult times, fishers are often extended credit to supplement living costs.

The main costs incurred by dealers/brokers and exporters in establishing LRFF capture and export operations are in the construction of the land-based holding facilities or floating cages, and the purchase of vessels, motors, and other fishing equipment. Identifying these costs is complicated by the trading structures within and between countries that involve several parties between sea and restaurant (Bentley, 1999). Floating cage construction costs in Indonesia are estimated to be around US$2500 per unit, while in Vietnam these costs range from A$800 to US$1200 (Bentley and Indrawan, 1999). In the Philippines, fish for grow-out are held in floating cages while fish ready for export are held in floating cages and land-based facilities; cage capital costs are estimated to be approximately US$1250 (Baliao *et al.* 2000). Capitalisation of land-based facilities in the Philippines is estimated at US$25,000–30,000 while in Australia, land-based facility costs are around US$200,000.

The traditional mode of transporting LRFF to markets was by ship operated by importers in Hong Kong. These special purpose live transport vessels range in size from 20–40 metres and are capable of transporting 12–20 tons of live fish over 10 000 km on voyages lasting 25–30 days. LRFF importers operate one or more live-fish carriers. Foreign agents in exporting countries are responsible for collecting and consigning adequate quantities of fish for export. One 15 tonne shipment of LRFF may cost importers up to US$250,000. Larger importers may own floating cage stations in Hong Kong and will also act as wholesalers if they have a large holding capacity.



Note: Boundaries are not necessarily authoritative.

Figure 1. Source countries for live reef food fish imported into Hong Kong, showing the expansion of the trade in successive decades into both the Indian and Pacific Oceans.

Source: Sadovy *et al.* (2004).

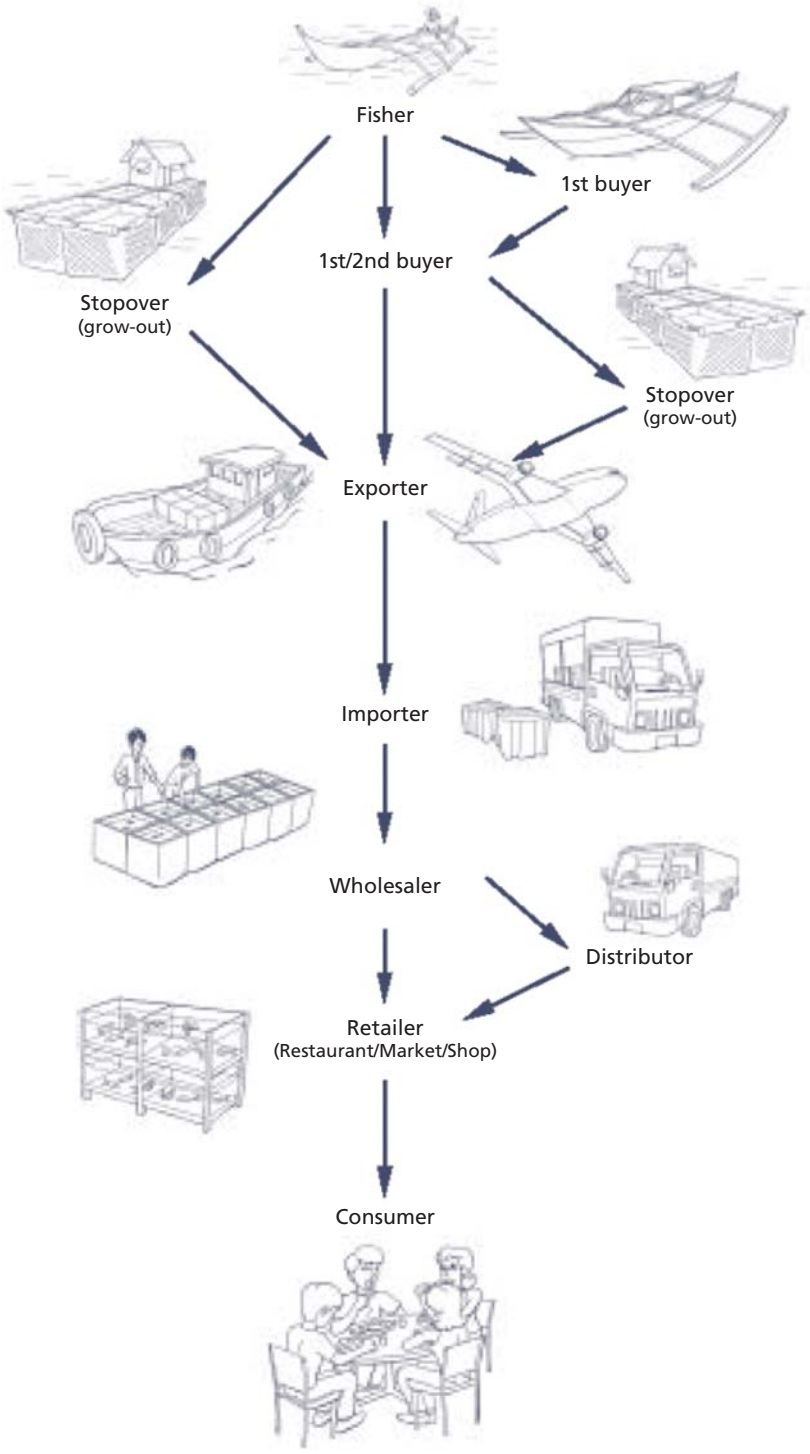


Figure 2. The trade structure for live reef food fish from fisher to consumer.
Source: (Sadovy *et al.*, 2004).

Improved shipping skills and technology (i.e. aerated transport bins) has seen a marked increase in the volume of fish being transported to Hong Kong markets by air from all major exporting countries. About 60% of all LRFF imported there now arrive by air. From Indonesia, almost 40%,in some areas up to 70%, of all LRFF are sent by air. From Australia, Malaysia, and the Philippines nearly all LRFF exports are delivered to Hong Kong by air. Thailand and Vietnam also rely heavily on air transport, with up to half of all exports being transported by this means (Pet-Soede and Erdmann, 1998; Bentley, 1999; Chan, 2000; Padilla *et al.*, 2003).

Modes of air transport differ widely. LRFF exported from Southeast Asia are transported in oxygenated plastic bags packed in polystyrene boxes. Exports from Australia are transported in large, moulded plastic, aerated or oxygenated bins. The latter can hold up to 300 kg of fish in 1 m^3 of water; almost five times the capacity of the polystyrene boxes. While transporting LRFF in bins is more cost-effective than polystyrene boxes, the cost of returning these bins to the originating exporter is high, adding considerably to the overall cost of freight.Polystyrene boxes used to transport fish from many Southeast Asian countries also represent an operating cost to buyers/exporters. These boxes are not re-used after reaching Hong Kong.

The cost to wholesaler/exporters of getting live product to Hong Kong usually consists of: the 'beach' price paid to fishers or middlemen; wage costs; fixed costs such as electricity and maintenance; and freight costs. Freight costs may include the cost of returning an empty transport bin to its point of origin. The costs of air-freighting LRFF to Hong Kong from Australia has been estimated at between $6.20 and $13.35 per kilogram depending on whether aerated or oxygen bins are used, with oxygen bins having greater capacity; the number of bins shipped at any one time; and the mode of transport by which bins are returned to Australia (Table 1).

Within Australia, composite operational costs (fixed annual and variable) of land-based facilities have been estimated at approximately A$10.00/kg of fish exported (L. Peterson, *pers. comm.*) The total cost to the exporter of obtaining and transhipping LRFF to Hong Kong is estimated at between A$46.50 and A$53.50/kg. These estimates are based on the assumption that exports consist solely of coral trout given that this species has comprised 90–95% of all Australian exports. A beach price of A$30/kg, based on average annual prices received by fishing operators for 2000/2001, was used. This cost can be compared against the average annual wholesale price in Hong Kong for live coral trout in 2000–01 of between A$60–65 (IMA Hong Kong, unpublished data).

Table 1. Freight costs to wholesale exporter transporting live fish from Cairns to Hong Kong. Costs include shipment to Hong Kong and bin return either by sea or air.

No. Bins	Total Cost (A$)	Capacity # of fish		Cost/kg (A$)		Bin Ret (A$)		Total costs/kg ($A) Bin return by sea		Total costs/kg (A$) Bin return by air	
		Aeration	Oxygen	Aeration	Oxygen	Sea	Air	Aeration	Oxygen	Aeration	Oxygen
1	1600	240	300	6.67	5.33	525	1000	8.85	7.10	13.35	10.65
2	3185	480	600	6.64	5.31	1050	1900	8.80	7.05	13.25	10.60
3	4355	720	900	6.05	4.84	1575	3000	8.25	6.60	12.10	9.70
4	5325	960	1200	5.55	4.44	2100	4000	7.75	6.20	11.10	8.90

Source: Goodsview Trading; Wholesale Fish Buyer, Cairns Queensland, unpublished data.

Changes in transport technology and practices (see Sadovy *et al.*, 2004) have resulted in lower rates of mortality along the market chain between export and import countries. Mortality during use of transport bins is reported to be <5% on average compared to 30–50% for sea transport

(L. Petersen, K. Vy, and P. Chan, *pers. comm.*). The uptake of transport bins has reduced holding times in source countries and transhipment times (from weeks to days). Furthermore, LRFF arrive in Hong Kong in better condition when air transport is used. Cage maintenance and associated holding costs (wages, feed etc.), while generally low in most developing countries, are difficult to quantify and vary according to the length of time fish are held prior to export. Holding times for LRFF sent by air are approximately 7–10 days from first sale, including reconditioning fish during transit. The greater volume of fish required to justify using a live-fish transport vessel means longer holding times and higher holding costs. Overall improvements in transport technology have reduced investment risks and improved cash flows for importers and exporters (Table 1).

Table 2. Transport and operating costs by transport mode for main export countries.

Region / Country	Operating Costs (US$/kg)		Transport Costs (US$/kg)	
	Broker	Exporter	Air	Sea
Southeast Asia				
Indonesia	n/a	n/a	3.00–3.50	4.50–5.00[a]
Philippines[b]	0.01	0.02	3.70–4.70	4.50–5.00[a]
Malaysia	n/a	n/a	1.50–2.00	4.50–5.00[a]
Vietnam[b]	0.03	0.05	~3.00	4.50–5.00[a]
Oceania				
Australia	not applicable	6.50	7.05[c]/8.80[d]	n/o
Fiji Islands		n/a	n/o	6.00–7.00[e]
PNG/Solomon Islands		n/a	n/a	4.00–4.50[e]
Indian Ocean				
Seychelles		n/a	n/o	6.00–7.00[e]
Maldives		n/a	n/o	4.70–5.40[e]

[a] Costs depend on quantity collected, fuel prices, and weather conditions affecting transportation times.
[b] Costs are daily costs per kilogram and include wages, fish food, and maintenance.
[c] Costs per kilogram by oxygenated bin (including cost of returning bin to origin).
[d] Costs per kilogram by aerated bin (including cost of returning bin to origin).
[e] Costs are based on a transport vessel capable of carrying up to 20 t, collecting 12–15 t of fish.

Note: n/a indicates data not available for that country while n/o means the mode of transport is not an option from that country.

Source: Sadovy *et al.* (2004).

As the quantity in each air shipment is relatively small, some retailers have started importing LRFF, avoiding the need to go through wholesalers. As a consequence, distinguishing between importers, wholesalers and retailers has become more difficult, although wholesalers retain the leading role in the trade (Chan, 2001).

The market chain and operational costs for cultured live reef fish

Aquaculture has been identified as an alternative livelihood to engaging in fishing practices that are often destructive. Aquaculture is also a means of meeting future demand for grouper species at a time when stocks of this species in Southeast Asia are showing signs of severe depletion. It is estimated that approximately 40 per cent of all LRFF are supplied from aquaculture, although the majority of these fish come from grow-out of wild-caught juveniles to market size (Sadovy *et al.*, 2004). With regard to the LRFF trade, aquaculture covers a range of activities from full-cycle aquaculture to grow-out of wild-caught juvenile and sub-adults for markets.

The market chain for aquacultured LRFF is not dissimilar to that of wild-caught LRFF, with the primary difference being during the production stage. Aquaculture of LRFF may involve several production stages and sectors. In Taipei for example, the production of eggs from broodstock, rearing of eggs, rearing of juveniles and grow-out of fish to market size are overseen by individual agents (Liao *et al.*, 1994). Similar production chains have appeared in Indonesia where clusters of 'backyard' hatcheries and land-based grow-out facilities co-exist. Some of the operators of these facilities on-sell juveniles to larger grow-out farms (Siar *et al.*, 2002). While culture production of groupers is expanding into other Southeast Asian countries, including the People's Republic of China, the Philippines, Thailand and Vietnam, it is still largely based on the collection and grow-out of wild-caught juveniles (Sadovy *et al.*, 2004). Within these countries, grow-out of grouper occurs both in land-based ponds and in coastal cages. Previous studies of grouper aquaculture have shown hatcheries and grow-out facilities to be highly profitable, with high internal rates of return (Baliao *et al.*, 2000; Siar *et al.*, 2002; Haylor *et al.*, 2003).

Table 3. Costs and revenues for humpback grouper hatchery production (all figures in Australian dollars).

Scale Survival rate Income Annual operating costs Maintenance (3% of Capital costs) Financial costs (18% interest on capital)	3 hatchery runs of 100 000 viable eggs 5% of 300 000 (15 000 eggs) $12,000 ($0.8 per fingerling) (USD 9,000) $6,330 (USD 4,750) $266 (USD 200) $1,593 (USD 1,200)
Total Annual Cost	$8,189 (USD 6,140)
Total Annual Profit	$3,811 (USD 2,860)

Source: Siar *et al.* (2002).

Fish mortality and transhipment costs (risk)

Fish mortality is not factored into the costs of transportation or the distribution of wealth among stakeholders (Table 3). Mortality remains a major factor, however, in the cost of delivering LRFF to markets to Hong Kong. Most fish deaths occur during the holding phase in the source country and during the transhipment phase.

The use of sea transport to deliver LRFF to markets usually requires the fish be held in floating cages for up to one month after capture. Mortality during the holding phase has been estimated to average as high as 50% between reef and retail, with estimates of up to 30% during the first 3–5 days of captivity. During these early phases, mortality is often the result of cyanide use, but has also been attributed to poor cage conditions, overstocking of cages, poor handling and feeding practices, and the spread of disease (Sadovy and Vincent, 2002).

While costs of shipping fish often compare favourably against shipping by air (see Table 2), they are tempered by two factors: the health of the fish, and supply and demand. As noted above, subsequent mortality is much lower when fish are freighted by air; mortality rates when using air transport bins are reported to average less than 5%. Mortality, particularly with sea transportation, is usually factored into the buying price at the import destination and is dictated by the condition of fish when collected, distance to market, and the supplier's history. Another factor dictating price is weight lost during transit, which can be as much as 15% (P. Chan, *pers. comm.*). Large live transport vessels (LTVs) shipments of up to 15 tonnes of LRFF may oversupply the market driving down price and eroding profits to the live fish trader.

The market chain — exporting country prices

Wholesale or beach prices

The beach price refers to the amount paid by the buyer for a fish when it reaches shore, prior to export. Wholesaler/middlemen and exporters in source countries, and importers in Hong Kong, pay higher prices for plate-size fish, while oversize fish fetch a slightly lower price. In Australia, fish less than the legal minimum length of 38 cm are rejected by wholesalers, while in the Philippines and Indonesia, where size limits are not enforced or not in place, all fish are purchased. Fish that are undersize receive around one quarter of the price paid for a good size fish (Padilla *et al.* 2003. Fish not ready for markets are moved to grow-out cages where they are held until they reach plate-size (and their value has increased). Payment may be made directly to a sole fisher or paid to a fishing operation that employs several fishers. The export price is generally the amount paid to the exporter by the overseas buyer, usually based in Hong Kong. This price will reflect costs incurred by the exporters to purchase fish from a broker/dealer, where applicable, as well as any holding and transportation costs incurred by the exporter.

Average beach prices received by fishers in the major exporting countries are shown in Table 4. The high prices paid for humphead wrasse in the Philippines and Malaysia recognise their proximity to market and the use of live-fish transport vessels to ship them. The significantly lower prices paid to Indonesia fishers for these high-value species does not reflect the high retail prices they attract. The lower price range for coral trout in Malaysia and the Philippines refers to undersize fish. While Filipino fishers are occasionally paid higher prices than fishers in Australia, Philippine catch rates are considerably lower than those in Australia. Padilla *et al.* (2003) estimate fishers on Coron catch 0.4 kg of fish/hour, while Mapstone *et al.* (2001) estimate that Australian fishers catch roughly 3.6 kg/hour. These prices do not reflect any obligations the fisher may have with the dealer to whom they sell their catch. The complexity of the market chain and the diverse relationship between fishers and dealers/buyers in different countries means that comparing beach price across countries is difficult.

A hypothetical market chain showing distribution of the final value of LRFF amongst the various agents along the chain is illustrated in Figure 3 (a) and (b).

The market chain — case studies

Case studies of distribution of final value have been undertaken in Australia and the Philippines. In Australia, fishers retain a greater percentage of the final value because they do not bear the variable costs associated with the fishing activity (i.e. hooks, bait, food and fuel). Filipino fishers must not only meet these costs but also pay instalments to financiers for debts for capital equipment; costs are deducted from the catch values before payment to the fishers (Table 3). Australian boat owners, effectively brokers, retain a smaller percentage of the final value than do their Filipino counterparts because they do not receive payment from fishers for use of capital equipment and their fixed and variable costs are higher. The lower net final value in Australia is attributed to higher transport and holding costs. High percentages attributed to end-users (restaurants) are due to high business costs.

Table 4. Average beach prices (US$) paid to fishers for selected species in the main exporting countries for 1999–2001.

Species	Country	Beach Price ($/kg)		
		1999	2000	2001
Humphead wrasse	Philippines[a,b]	45–50	55–60	55–60
	Indonesia[c]	8–10	10–15	10–15
	Australia[d]	9–10	8–9	9–10
	Malaysia[e]		55–60	55–60
Humpback grouper	Philippines[a,b]	45–50	55–60	55–60
	Indonesia[c]	8–13	10–15	10–15
	Australia[d]	~29	~26	~24
Leopard coral grouper	Philippines[b,f]	8–28	7–27	7–27
	Indonesia[c]	6–10	6–12	6–12
	Australia[d]	12–26	12–33	14–25
	Malaysia[e]	10–25	10–25	10–25
	Vietnam[f]		10–17	10–15
Tiger/flowery grouper	Philippines[b]	7–12	8–12	8–12
	Indonesia	1–2	1–2	1–2
	Australia[d]	5–6	4–6	3.5–5
Orange-spotted Grouper	Philippines			8–9
	Indonesia	1–2	1–2	1–2
	Vietnam[g]		5–9	6–10
	Thailand[h]	5–8	5–8	5–8

[a] Beach price paid per piece.
[b] Total price paid by wholesaler/exporter. Fisher receives approximately 30% of total price and dealer 70% (Palawan Council for Sustainable Development).
[c] Price varies depending on location; fishers in some areas receive less than half of the price paid by dealers in other parts of Indonesia (Erdmann and Pet, 1999).
[d] Total prices paid to vessel owner. Fisher receives 20% of market value for all species.
[e] Lower price ranges are for undersized fish (<0.5 kg) for grow-out. Upper range is for good size fish (0.5–1.0 kg) ready for market (Chan, unpublished data).
[f] Lower price ranges are for undersized fish (<0.5 kg) for grow-out. Upper range is for good size fish (0.5–1.0 kg) ready for market. For fish greater than 1.0 kg price is paid per piece (Bentley, 1999).
[g] McCullough and Phung Giang (2001); IMA Viet Nam (unpublished data).
[h] Lower price ranges are for smaller fish for grow-out. Upper range is for good size fish (0.5–1.0 kg) ready for market (Chan, unpublished data).

Notes:
These data have been verified where possible by the Hong Kong, China, Chamber of Seafood Merchants.
Prices do not take into account any other deductions made by the buyer for debts owed.

Source: Sadovy et al., 2004).

Price co-integration — issues for further research?

Several studies have examined prices and margins along seafood chains, including the impacts of technological change (e.g. aquaculture) on these chains. Most studies use *co-integration* analysis to examine long-run relationships (Asche *et al.*, 1998; Ferreira Dias *et al.*, 2003 Asche *et al.*, 2002; Guillotreau, 2003). In most cases a Hicksian model linking the derived demand elasticity to the final price elasticity is used. Assuming that the derived demand elasticity is equal to the consumer elasticity, co-integration can test for whether prices at different stages of the market

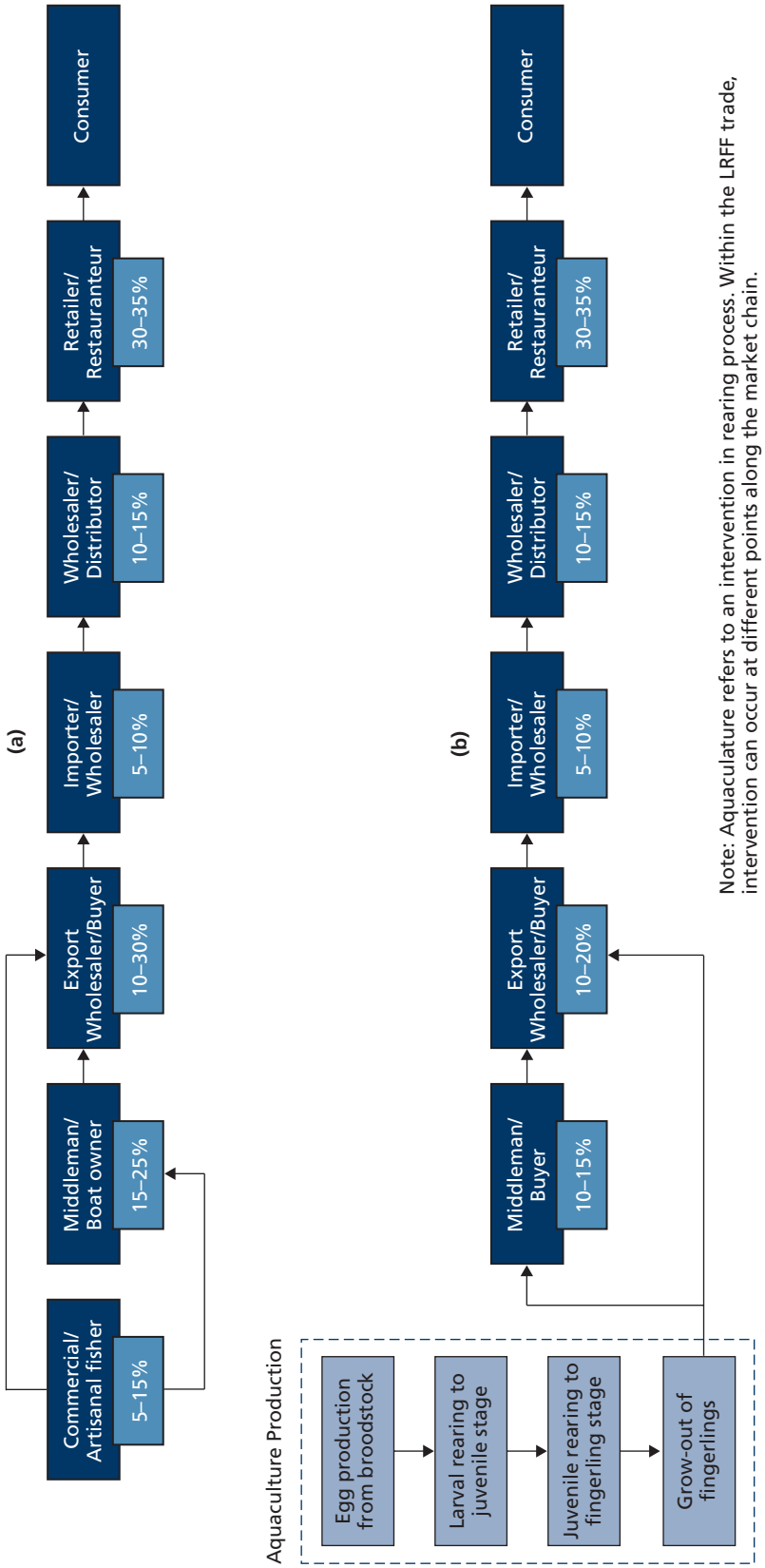


Figure 3. Hypothetical Economic Value Chain Model for: (a) wild-caught live reef food fish and (b) farmed live reef food fish. The percentage represents the estimated % of the consumer dollar extracted at that link of the chain.

Source: Muldoon, unpublished data.

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chain are moving synchronously in the long run (i.e. statistically co-integrated). The success of co-integration analysis depends on the availability of long-term and non-stationary (i.e. when its mean and variance are not constant) time series price data (Gonzales *et al.*, 2002) (see Asche *et al.*, 1998) for discussion on making data stationary). Co-integration techniques can be used to examine price variability, either upstream (closer to producer) or downstream (closer to retailer) by testing relationships between price margins or mark-ups (i.e. proportionality along the chain) and the strength of price transmission (Hartmann *et al.*, 2000). Further procedures can test for *weak exogeneity* of prices to establish which segment of the market chain is influencing prices along the chain. Exogeneity describes whether price determination occurs at the downstream (closer to retail) or upstream ends of the market chain. Most co-integration studies have examined large-scale industrial fisheries with good datasets, as opposed to small-scale artisanal fisheries.

Table 5. Wealth and income distribution along the market chain, based on average monthly retail and wholesale values (US$) in Hong Kong for leopard coral grouper.

Australia (Great Barrier Reef, Queensland)

	Fisher	Boat owner	Exporter	Importer/ Retailer	End user	Final value
Share of Gross ($)	3.50	12.10	24.40	8.65	20.20	68.85
Share of Gross (%)	5.1	17.6	35.4	12.6	29.3	100.0
Net/kg ($)	3.50	2.40[a]	9.75[b]	1.75[c]	10.10[d]	27.50

[a] Based on boat-owner retaining about 20% of gross after fixed (e.g. licence) and variable (e.g. fuel, bait) fishing costs.
[b] Based on exporter retaining about 40% of gross after fixed and variable (e.g. utilities, wages, freight, food) costs of storing and transporting live fish by air.
[c] Based on importer retaining about 20% of gross after fixed and variable (utilities, wages, freight, food) costs of storing and transporting live fish to retail markets
[d] Based on restaurateur retaining about 50% of gross after payment of fixed and variable costs.

Philippines (Coron)

	Fisher	Middleman /Dealer	Exporter	Importer/ Retailer	End user	Final value
Share of Gross ($)	7.80	15.70	11.80	9.90	23.60	68.80
Share of Gross (%)	14.3	22.9	14.3	14.3	34.2	100.0
Net/kg ($)	2.35[e]	7.85[f]	7.10[g]	2.00[h]	11.80[i]	31.10

[e] Based on fisher retaining about 30% of gross after debt repayment and fuel, bait etc purchase.
[f] Based on dealer retaining about 50% of gross after fixed and variable (utilities, wages, freight, food) costs of storing and transporting live fish, (fisher debt repayment not included).
[g] Based on exporter retaining about 60% of gross after costs of storing and transporting live fish by air.
[h] Based on importer retaining about 20% of gross after fixed and variable (utilities, wages, freight, food) costs of storing and transporting live fish to retail markets.
[i] Based on restaurateur retaining about 50% of gross after payment of fixed and variable costs.

Note: Retail = $68.80 and wholesale = $40.00 prices are from February 2001. Prices are based on the sale of a market-size fish weighing 0.5–1.0 kg.

Source: Sadovy *et al.* (2004).

For many seafood products 'margin-pricing' is used by agents whereby a mark-up is added to the variable cost to cover overheads and yield a net profit. Margin pricing implies that demand elasticities for consumers and intermediaries will coincide and lower level data (e.g. wholesale or import prices) can be used to derive information about consumer demand (Asche *et al.*, 1998).

Derived demand own-price input elasticity for inputs and consumer demand own-price elasticity η will be equal where intermediaries' production technology can be measured by one variable input α (i.e. mark-up or margin pricing) such that:

$$E_{\alpha} = \eta$$

If we accept this, then testing for proportionality of prices along the market chain can be performed using only price data (Asche *et al.*, 1998). Using producer level data to estimate consumer or retail demand is also possible where proportional relationships exist between relevant market chain links (Hartmann *et al.*, 2000). For international trade, this enables, for example, testing if trends in export prices in source countries are consistent with trends in wholesale and retail prices in importing countries. Extensions of this approach may be used to understand interactions along the value chain where exogenous shocks (i.e. stock depletion, quota reduction, increased fishing effort and aquaculture innovations) are transmitted to industry (wholesalers, retailers).

Research has shown that price volatility is often not transmitted along the chain with various processors and wholesalers acting as buffers for producers (i.e. fishers). Lower price variability closer to downstream (consumer) markets is more common with processed products (Gonzales *et al.*, 2002), while it has been observed that price transmission is more likely where downstream prices drive market forces; a factor not apparent in the LRFF trade. Product form can dictate the strength and pace of price transmission with transmission more evident for processed as opposed to fresh fish, due probably to the supply of fresh fish being more inelastic to price (i.e. supply responses are hampered by biological and weather constraints). Lastly, price adjustments tend to be transmitted more rapidly (especially to consumers) for farmed as opposed to wild-caught products, again due to uncertainty faced by various agents along the market chain for wild-caught product.

In terms of exogeneity, the downstream price (import price) for fresh fish is shown to be weakly exogenous in the relationship with retailers and wholesalers, a result consistent with greater uncertainty (Gonzales *et al.*, 2002 Ferreira Dias *et al.*, 2003). Note that exogeneity does not imply price-setting status for the agent whose price is exogenous, it is more the direction in which price is being transmitted. For example, retailers may allow suppliers to set their prices based on variable fishing costs, and not consumer demand, with these costs in turn driven by stock and effort constraints. Thus greater variability in upstream prices may be due to: (i) uncertainty driven exogeneity of prices; and (ii) retailer pricing polices, whereby standard profit margins are added to supply costs with this behaviour amplified where products are more perishable (Gonzales *et al.* 2002)

In co-integration, demand functions for seafood should be negative and with fairly high own-price elasticity (Asche and Bjorndal, 1999; Steen *et al.*, 2000) Analysis shows a tendency for demand closer to the consumer (e.g. retail demand) to be more elastic than demand closer to the producer (e.g. ex-vessel demand) (Petersen *et al.* 2004). In such instances, variability in price should stem mainly from the supply (upstream) side. Results from related research show that own-price elasticities for low and medium-value live reef fish are low (–0.30, –0.16 respectively) while own-price elasticity of 0.33 for high-value live reef fish is both low and positive. For individual species, only green grouper (–1.18) of the low-value species and tiger grouper (–2.47) of the medium value species exhibit 'usual' own-price elasticities. Of the high-value species, own-price elasticity estimates for humpback grouper may be small and positive (0.76) (Petersen *et al.* 2004).

In terms of aquaculture, there has tended to be an increase in concentration of firms along the market chain. Subsequent redistribution of value favours larger retailers and processors and increased vertical coordination between successive stages of the chain. Overall, price transmission remains competitive and consumers benefit from increased availability of farmed fish (Guillotreau, 2003; Tveteras and Kvaloy, 2003). There is evidence of *long-run price integration* in Vietnamese aquaculture markets, although localised shortages can cause localised price changes (van Anrooy, 2003).

Empirical and anecdotal evidence available for the LRFF trade suggests that the direction and strength of price transmission is in contrast to that described above for European fresh fish markets. Normal transmission of prices is distorted by convoluted business relationships between multiple agents along the chain. For example fishers may be financially beholden to middlemen, and middlemen and exporters in supply countries to importers or wholesalers in importing countries. Also, price collusion in exporting and importing countries often means price-setting is controlled by downstream agents, perhaps as far down as retailers and wholesalers.

Ideally, prices should move mutually in the long-run, allowing for freight, processing and marketing costs. However exchange rate movements may distort this movement. For price-cost margins that are not constant over time, the cause may be market power, transaction costs (e.g. freight) or other more fundamental structural problems. Limited data is available on prices along the market chain and no studies have tested for proportionality between retail, wholesale, import and export market prices within the LRFF trade. Such research, while desirable, would be hindered by a lack of reliable time-series data but further investigation would be relevant (Figure 4).

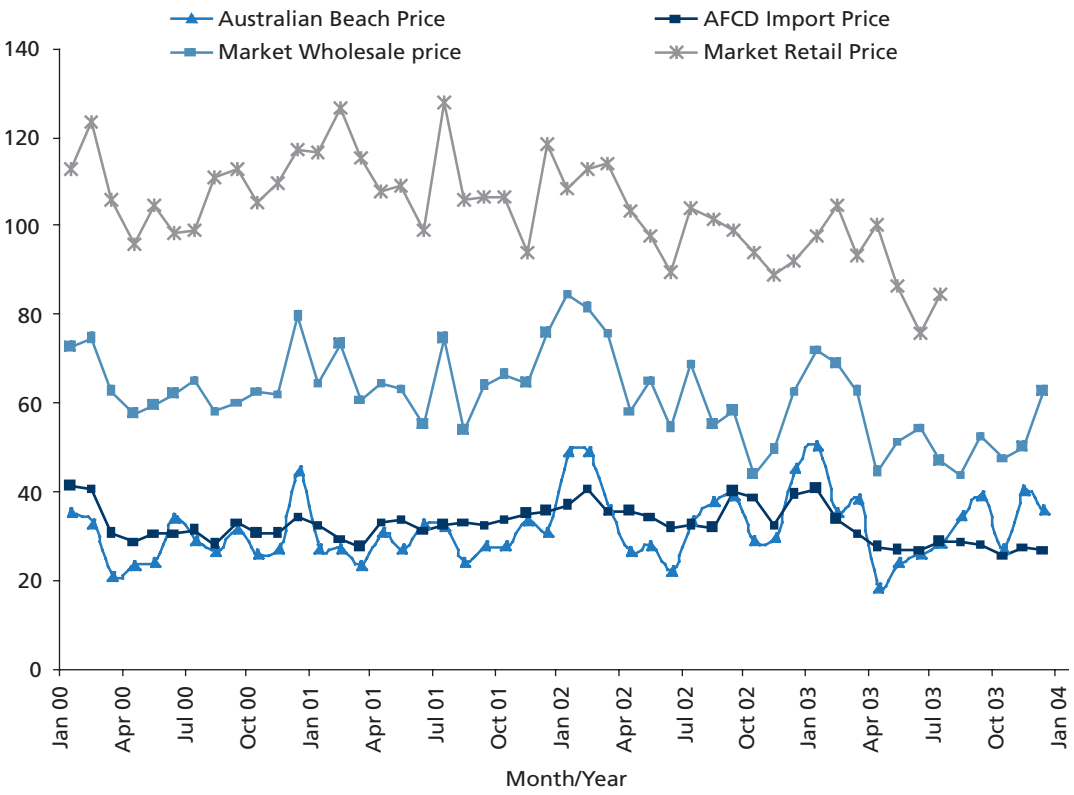

Figure 4. Price comparison at various stages along the market chain for coral trout (Plectropomus leopardus) sourced from the Great Barrier Reef Marine Park, Queensland for the period January 2000 to December 2003.

Source: Agriculture Fisheries and Conservation Department Hong Kong, unpublished data; International Marinelife Alliance Hong Kong, unpublished data; G. Muldoon unpublished data.

Concluding comments

Live reef food fish are a high value commodity in the under-developed and historically low-income regions from where many of these fish are sourced. Value-adding fisheries such as these can offer much needed income opportunities for the fishing communities in these regions. An extended market chain has developed between the upstream suppliers (fishers) and downstream buyers and distributors in the LRFF trade due to a number of factors, such as the use of low technologies and remoteness of fishing grounds. With the extended market chain for LRFF, the gains at each point along the chain have tended to be unevenly distributed for a variety of reasons including limited market information, value of capitalised assets, non-responsive behaviour by fishers in source countries, fluctuating market conditions and distribution of risk. These distortions along the market chain have been further complicated by increasing supplies of cultured fish as direct substitutes for wild-caught species.

The first step in understanding the market chain issues, such as relative margins accruing to upstream and downstream agents, price transmission and market power, is to undertake co-integration analysis. In the first instance, data collected on wholesale and retail prices in Hong Kong will be used to test for proportionality of prices in demand markets. While sufficient data is available to examine price interactions in demand markets, with the exception of Australia, there is a paucity of usable data from supply markets. Price data for countries supplying fish to the LRFFT will be used by researchers in this project to undertake co-integration analysis to test for prices proportionality between export and import markets.

Data availability will determine whether co-integration analysis can be used to understand exogenous influences on the market chain arising from the adoption of new transportation and aquaculture production technologies, specifically: (i) the supplanting of traditional sea with air transport, which may lessen ecological impact[2], lower holding mortality and reduce the use of trash fish to feed LRFF; and (ii) the market impacts, and specifically price impacts, that substituting wild-caught for cultured species may have on price transmission and margins along the chain.

In the likely event of limited data being available for use in quantitative analyses, qualitative and scenario-based assessments of the LRFF trade market chain could be undertaken to: (i) determine the constraints in the market chain that are hindering linkages and devise strategies and methods to remove or mitigate these constraints; and (ii) assess the impact of growth in LRFF mariculture on existing supply and demand relationships in the market potential contribution of mariculture in assisting the long-term sustainability of the trade. This will be in collaboration with the ACIAR mariculture projects FIS/2002/077 'Improved hatchery and grow-out technology for marine finfish aquaculture in Asia–Pacific region' and FIS/2003/027 'Environmental impacts of marine cage aquaculture in Australia and Indonesia'.

References

Asche F., Salvanes K.G. and Steen F. 1997. Market delineation and demand structure, American Journal of Agricultural Economics, 79(1): 139–150.

Asche F., Flaaten O., Isaksen J. R. and Vassdal T. 1998. Derived demand and price relationships: An analysis of the Norwegian cod sector. In: Eide and Vassdal (eds) Proceedings of the 9th International Conference of the International Institute of Fisheries Economics and Trade, Tromsø, Norway, 1998.

[2] With fewer fish required per shipment, opportunities for a small-scale fishery that is both economically and ecologically viable present themselves.

Asche F. and Bjorndal T. 1999. Demand elasticities for fish: A review. Available at https://www.globefish.org/publications/speicalseries/vols/Vol09/SSE0800.htm as at July 2003.

Asche F., Flaaten O., Isakse J.R. and Vassdal T. 2002. Derived demand and relationships between prices at different levels of the value chain. Journal of Agricultural Economics, 53: 101–107.

Baliao D.D., de los Santos M.A., Franco N.M. and Jamon N.R.S. 2000. Grouper culture in floating net cages. Iloilo, Philippines: Aquaculture Department, Southeast Asian Fisheries Development Center.

Bentley N. 1999. Fishing for solutions: Can the live trade in wild groupers and wrasses from Southeast Asia be managed? Petaling Jaya, Selangor: TRAFFIC Southeast Asia.

Bentley N. and Indrawan M. 1999. The live reef food fish trade in the Banggai Islands (Suluwesi, Indonesia): A case study. In: N. Bentley (ed.) Fishing for solutions: can the live trade in wild groupers and wrasses from Southeast Asia be managed Petaling Jaya, Selangor: TRAFFIC Southeast Asia.

Chan P.S.W. 2000. Current status of the live reef fish trade based in Hong Kong. SPC Live Reef Fish Information Bulletin, 7: 8–9.

Chan P.S.W. 2001. Wholesale and retail marketing aspects of the Hong Kong live seafood business. In B. Paust and A. Rice (eds). Proceedings of the second international conference: Marketing and shipping of live aquatic products. November 1999, Seattle. University of Alaska Sea Grant (AK-SG-01-03) p 201–205).

Christensen V. and Pauly D. 1998. Changes in models of aquatic ecosystems approaching carrying capacity. Ecological Applications 8(1): 104–109.

Engle R.F. and Granger C.W.J. 1987. Cointegration and error correction: representation, estimation and testing. Econometrica 57: 3999–409.

Erdmann M.V. and J. Pet. 1999. Krismon and DFP: Some Observations on the Effects of the Asian Financial Crisis on Destructive Fishing Practices in Indonesia. *SPC Live Reef Fish Information Bulletin* 5: 22–26

Ferreira Dias J., Menezes R., Filipe J.C., Guia F., Guerreiro V. and Asche F. 2003. Short and long run dynamic behavior of the cod value chain for Norway-Portugal. In Proceedings of the XV European Association of Fisheries Economists Conference, IFREMER, Brest, France 2003.

Ferris R.S.B., Collinson C., Wanda K., Jagwe J. and Wright P. 2001. Evaluating the marketing opportunities for shea nut and shea nut processed products in Uganda. A report prepared for USAID. 77 pp.

Fitter R. and Kaplinsky R. 2001. Who gains from product rents as the coffee market becomes more differentiated? A value-chain analysis. International Development Studies Bulletin. 32 (3): 69–82.

Gonzales F., Guillotreau P. and Le Grel, L. 2002. The transmission of price variability along the French cod value chain. In: Proceedings of the XIVth European Association of Fisheries Economists Conference, Faro, Portugal 25-27 March 2002.

Gordon D.V., Salvanes K.G. and Atkin F. 1993. A fish is a fish is a fish: testing for market linkages on the Paris fish market. Marine Resource Economics, 8: 331–343.

Guillotreau P. 2003. Prices and margins along the European seafood value chain. In Proceedings of the XV European Association of Fisheries Economists Conference, IFREMER, Brest, France 2003.

Hartmann J., Jaffry S. and Asche F. 2000. Price relationships along the value chain: An analysis of the hake market in France. In: Proceedings of the 10th International Conference of the International Institute of Fisheries Economics and Trade, Oregon, USA, 2000.

Haylor G., Briggs M.R.P., Pet-Soede L., Tung, H., Yen N.T.H., Adrien B., O'Callaghan B., Gow C., Devantier L., Cheung C., Santos R., Pador E., de la Torre M., Bulcock P. and Savage W. 2003. Improving coastal livelihoods through sustainable aquaculture practices: A report to the Collaborative APEC Grouper Research and Development Network (FWG/01/2001). STREAM Initiative. Bangkok: Network of Aquaculture Centers in Asia–Pacific.

Jacinto E.R. 2004. A research framework on value chain analysis in small scale fisheries. Paper presented to the 10th Biennial Conference of the International Association for Study of Common Property, Oaxaca, México, 9–13 August 2004. 27 pp.

Kaplinsky R. 2000. Spreading the gains from globalisation: what can be learned from value chain analysis. Institute of Development Studies (IDS), IDS Working paper No. 110, Brighton.

Kaplinsky R. and Morris M. 2003. A handbook for value chain research. A report prepared for the International Development Research Centre, Institute of Development Studies, Brighton, UK 113 pp.

Liao I.C., Su M.S. and Chang S.L. 1994. A Review of the Nursery and Growout Techniques of High-value Marine Finfishes in Taiwan. In *Culture of High-Value Marine Fishes in Asia and the United States*, edited by K.L. Main and C. Rosenfield. Honolulu: Oceanic Institute. pp 121–137.

MacFadyen G., Banks R, Banks R., Phillipps M., Haylor G., Mazaudier L. and Salz P. 2003. Background paper on the international seafood trade and poverty. Prepared under the EC-PREP project (EP/R03/014), 'International Seafood Trade: Supporting Sustainable Livelihoods among Poor Aquatic Resource Users in Asia'. Poseidon Aquatic Resource Management Ltd (UK), Network of Aquaculture Centres in Asia–Pacific and STREAM Initiative.

Mapstone B.D., Davies C.R., Slade S.J., Jones A., Kane K.J., Williams A.J. 2001. Effects of Live Fish Trading and Targeting Spawning Aggregations on Fleet Dynamics, Catch Characteristics, and Resource Exploitation by the Queensland Commercial Demersal Reef Line Fishery. FRDC Technical Report 96/138. CRC Reef Research Centre, Townsville. 72 pp.

McCullough B. and H. Phung Giang. 2001. The Live Reef Fish Trade in Vietnam: A Preliminary Report from the Field. *SPC Live Reef Fish Information Bulletin*, 8: 12–164 Noumea, New Caledonia

Olivier K. 2001. The ornamental fish market. FAO/GLOBEFISH Research Program. Vol. 67. FAO. Rome. 91 pp.

Padilla J., Mamaug S., Braganza G., Brucal N. and Yu D. 2003. Sustainability assessment of the live reef-fish for food industry in Palawan, Philippines. Manila: World Wildlife Fund, Philippines. 70 pp.

Pauly D. 1998. Tropical fishes: patterns and propensities. p. In: T.E. Langford, J. Langford and J.E. Thorpe (eds.) Tropical fish biology. Journal of Fish Biology, 53: 1–17.

Pet-Soede L. and Erdmann M.V. 1998. An overview and comparison of destructive fishing practices in Indonesia. SPC Live Reef Fish Information Bulletin, 4: 28–35.

Petersen E.H., Muldoon G. and Johnston B. 2004. Finding Nemo: Estimating import demand for live reef food fish. Paper presented at the 7th Asian Fisheries Forum, 29 November to 3 December 2004, Penang, Malaysia.

Sadovy Y.J. and Vincent A.C.J. 2002. Ecological issues and the trades in live reef fishes. In: P.F. Sale (ed.) Coral reef fishes. Dynamics and diversity in a complex ecosystem. Academic Press, San Diego, pp 391–420.

Sadovy Y.J., Donaldson T.J., Graham T.R., McGilvray F., Muldoon G.J., Phillipps M.J., Rimmer M.A., Smith A. and Yeeting B. 2004. While stocks last: the live reef food fish trade. ABD Pacific Studies Series. Asian Development Bank, Manila.

Wolfe S. 2002. Potential Benefits of Functional Foods and Nutraceuticals to the Agri-Food Industry in Canada. Final report submitted to Agriculture and Agri-Food Canada, Food Bureau, March 2002. Scott Wolfe Management. 76 pp.

Siar S.V., Johnston W.L. and Sim S.Y. 2002. Study on Economics and Socio-economics of Small-scale Marine Fish Hatcheries and Nurseries, with Special Reference to Grouper Systems in Bali, Indonesia. Report prepared under APEC Project FWG 01/2001 — Collaborative APEC Grouper Research and Development Network. Asia–Pacific Marine Finfish Aquaculture Network Publication 2/2002. Bangkok: Network of Aquaculture Centers in Asia–Pacific. 36 pp.

Steen F., Asche F., Clayton P., Jaffry S., Le Grel L., Pascoe S. and Tuncel M. 2000. The implications for fisheries management systems of interactions between farmed and wild caught species. Final Report of the DEMINT Project, European Commission, DG 14, SNF, 157.

Stevens C. 2001. Value chains and trade policy: the case of agriculture. International Development Studies Bulletin, 32 (3): 14–29.

Tveteras R. and Kvaloy O. 2003. Vertical coordination in the salmon supply chain. In: Proceedings of the XV European Association of Fisheries Economists Conference, IFREMER, Brest, France 2003.

van Anrooy R. 2003. Vertical cooperation and marketing efficiency in the aquaculture products marketing chain: A national perspective from Vietnam. Paper presented to the Aquamarkets 2003 Conference. Manila, Philippines 2–4 June 2003.

Wood E.M. 2001. Collection of coral reef fish for aquaria: global trade, conservation issues and management strategies. Marine Conservation Society, UK. 80 pp.

14. Development of a spreadsheet model of the market chain for the live reef food fish trade

Geoffrey Muldoon[1] and Bill Johnston[2]

Introduction

The market for live reef fish for food (LRFF) is longstanding in Southeast Asia, with demand for live fish concentrated in Hong Kong and southern China. The total regional trade in LRFF is considered to be around 30 000 tonnes per year with an estimated 15–20 000 tonnes of this going into Hong Kong (Sadovy *et al.*, 2004). More than 20 countries in Southeast Asia and the Pacific supply fish to this market using a variety of capture techniques and transport technologies. LRFF is, by comparison to other fishery products, a high value commodity with average prices paid by consumers ranging from US$40/kg for low value species to more than US$100/kg for high value species (IMA Hong Kong, unpublished data).

A key component of this project (ADP/2002/105: Economic and market analysis of the Live Reef Food Fish Trade in Asia–Pacific) is aimed at identifying and measuring major cost and revenue components along the marketing chain using a spreadsheet model. This model will be further developed to incorporate key risk factors for the various agents along the chain from the point of capture to the point of sale; and for the case of both sea and air transport technologies. It is anticipated that the model will be modified for use and application in Australia and at least two Southeast Asian countries and two Pacific Island countries. This paper is a description of the preliminary scoping and development of the spreadsheet model for the marketing chain through an overview of the market chain (section 2), followed by a schematic representation of the development of the model components and the work done to date (section 3). Section 4 addresses the distribution of value in the context of risk and how this is included in the model. The final section summarises constraints and limitations and identifies future activities to be undertaken on market chain issues as part of this project.

The live reef food fish trade market chain

A number of factors determine the percentage of the final value extracted at certain points along the market chain, in particular market chain complexity and risk. Complexity refers to the collective number of agents in the supply chain in exporting and importing countries (MacFadyen *et al.*, 2003). The complexity of the market chain may expand or contract depending on the country of product origin, market sophistication/maturity and the distance of fishing grounds (i.e. fisher) from major infrastructure, which will dictate storage and transport facility requirements. Fishing ground remoteness, along with handling and husbandry techniques will also dictate risk of product loss faced by the various agents (see Sadovy and Vincent (2002) for a discussion of poor handling and husbandry practices along the supply chain contributing to higher mortality levels). Other factors that influence distribution of value include: (a) the amount

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of processing required to prepare a product for consumer markets; (b) storage and transportation requirements of the product; and (c) the perishable nature of the product.

Market chain analysis can help to identify constraints (e.g. information flows), inequities (e.g. distribution of value) and practices (e.g. handling, quality control) along the chain that can serve to enhance benefits of trade to agents, especially those upstream agents in source countries. Within the LRFF trade however, addressing these market chain constraints and inequities can be obstructed by relationships between agents along the market chain.

The characteristics of the LRFF trade have resulted in the market chain becoming quite extended and complex. These characteristics include rudimentary storage and transport infrastructure, low technology fishing gear, the remoteness of fishing grounds from supply hubs and the considerable distances of source countries from markets. After being caught by the fisher, LRFF pass through many levels of trade before reaching restaurants in Hong Kong and China. The market chain can be shorter in some countries than in others. In Southeast Asia, the supply side of the market chain includes one or two middlemen whose role is to consolidate catches from independent fishers into sufficient quantities for movement along the chain. In Australia, the middleman role is assumed by fishing firms who employ fishers to catch fish and who sell these fish directly to wholesale exporters. In Australia, LRFF fishers receive a percentage of the 'beach price' paid to the fishing firm by the export wholesaler. The chain is shorter still in the Pacific with fishers being employed directly by exporters who tranship this catch, almost entirely by sea.

As a high value commodity, there is a perceived potential for high economic gains along the chain. The high price of LRFF in Hong Kong has created an impression among suppliers from importing countries that the prices they receive from buyers one step further along the chain is too low (Chan, 2001). In the extended market chain for LRFF however, each agent requires an acceptable margin to continue trading. In practice these gains tend to be unevenly distributed among agents for a variety of reasons including: fishers' lack of knowledge of final values; transport costs incurred by traders when shipping fish across large distances either by sea or air; the high risks of mortality endured by traders during transport; heath scares (e.g. ciguatera); and shocks in economic conditions (e.g. Severe Acute Respiratory Syndrome (SARS)). A hypothetical market chain, showing distribution of the final value of LRFF amongst the various agents along the chain for wild-caught LRFF, is shown in Figure 1.

While horizontal cooperation at various stages along the chain does occur, vertical cooperation, or integration, is more likely in fishery chains as a result of:

- the perishability of the product
- variations in product quantity and quality
- consumer awareness of product quality
- economies of scale.

Within the LRFF trade, opportunities for vertical cooperation exist in both the wild-caught and aquaculture sectors. Vertical integration along the market chain for wild-caught LRFF usually occurs at the collection/export stage of the source country supply chain and the import/distribution stage of the import country supply chain (Figure 1). These vertical relationships will tend to obfuscate efforts to identify the distribution of final product value along the market chain. The individual agents will tend not to set prices or margins in line with their respective business operations; margins will be centrally determined for each of these 'profit centres'.

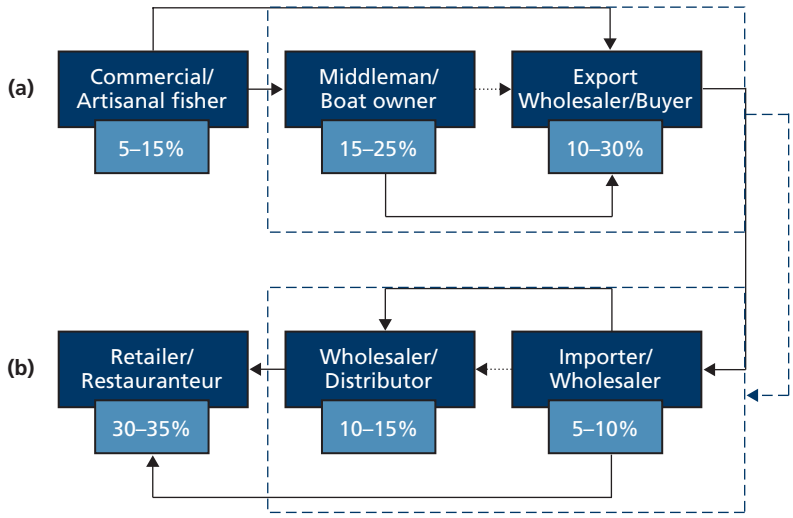

Figure 1. Economic value chain model for wild-caught live reef food fish for: (a) the supply or export; and (b) the demand or import sectors of the market chain. Percentage is an estimate of the final consumption value extracted at that link of the chain. The dashed boxes at export and import stages along the chain and the dashed line between these stages indicate vertical linkages between market chain agents.

In terms of LRFF aquaculture, there has tended to be an increased dis-aggregation at the upstream end of the market chain with increased specialisation in the production process. Hatchery, nursery and grow-out phases of LRFF aquaculture tend to be distinct components in the production stage. Vertical coordination between successive stages of the chain will occur where benefits can be demonstrated in terms of flexibility to meet variant demand conditions, access to product quality information, implementation of quality control activities and access to credit (van Anrooy, 2003).

Schematic of the market chain model

The current trade in LRFF is largely unregulated resulting in over-exploitation of fish stocks. It has been argued that this lack of regulation has meant small scale fishers are not receiving fair economic returns. The rationale for this has been that downstream agents bear the trade risks (i.e. fish mortality, exchange rate fluctuations and high transport costs) and these costs are passed back along the chain, leading to the relatively low prices paid to fishers (see section 4).

The key objective of this project component is to measure cost and risk components of the market chain to enable options for risk reduction, improved price transparency and improved returns for small scale fishers to be examined. There are two approaches to deriving what constitutes a fair economic return:

(i) A bottom-up approach of determining the costs of catching fish to derive a '*fair*' beach price that captures this cost plus a suitable margin.

(ii) A top-down approach based on the equitable distribution of the final product value (i.e. retail price) between agents based on risks and costs (e.g. transport, holding etc.).

Developing a bottom-up market chain model for the LRFF fishery is problematic for two related reasons. Firstly, there is a paucity of usable data, with the exception of fishing and export operations in Australia, that would enable a market chain model to be fully populated. Secondly, vertical integration between agents hampers the development of discrete sub-models for specific agents. The LRFF market chain is slightly more complex than traditional food industry value

chains (Wolfe 2002), through the inclusion of middlemen (Sadovy *et al.*, 2004). Traditional food industry chains consist of: producer, wholesaler, exporter, importer and retailer.

The initial spreadsheet models developed have used a hybrid top down approach. The model suite consists of two sub-models: one for fishers and fishing operations or middlemen (Figure 2); and the other for remaining market chain agents consisting of exporters, importers, distributors and retailers (Figure 3).

The fisher/middleman or fisher/fishing vessel sub-model

The fisher sub-model allows for costs to be derived using effort parameters and total revenues to be derived using catch parameters. Revenues can be based on either empirical beach price data or by using a margin-based approach, again using empirical evidence. Beach prices can also be used to derive margins based on costs. Total cost and revenue information are subsequently used to develop indicators of economic returns including: net present value; annualised returns; internal rates of return and rates of return on capital (Figure 2).

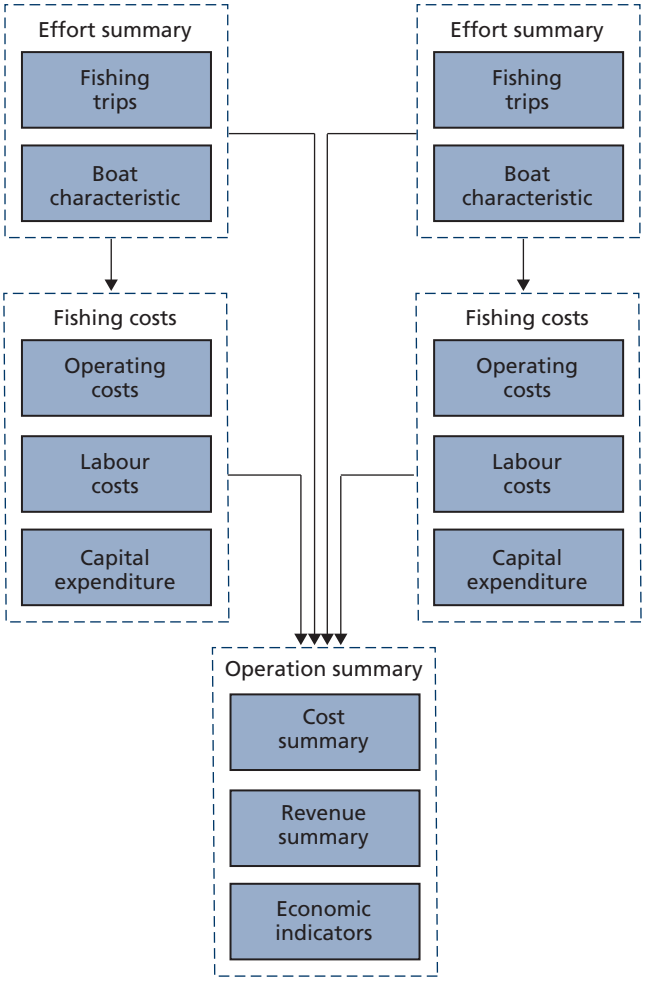

Figure 2. Schematic of fisher sub-model showing relationship between fishing costs and fishing effort and between fishing revenues and fish catch. Costs and revenues generate economic performance indicators.

The supply chain sub-model

In recognition of the lack of data available, a simplified model has been developed to schematically represent the supply chain (Figure 3). The current model incorporates wholesaler/exporter, importer/distributor and retailer margins based on empirical evidence. The model allows for these margins to be adjusted to explore the impacts of different margins on returns to agents and also to aid in examining the issue of 'fair price'. The option to validate these margins based on key cost parameter will also be made available. Exchange rate movement risks have been accounted for using an expected value probability model (Figure 4).

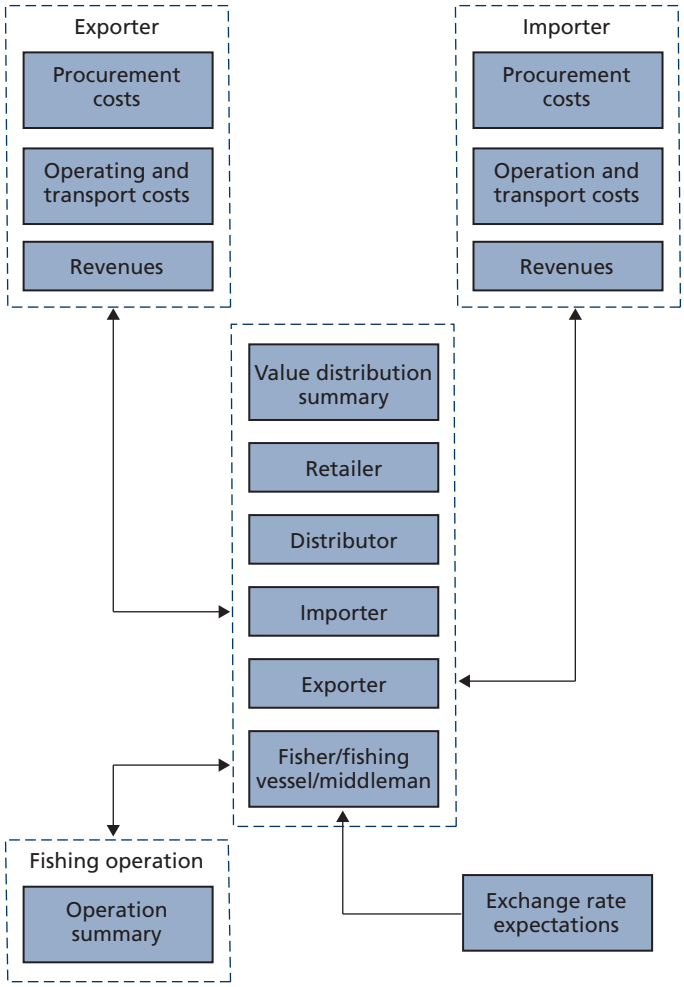

Figure 3. Schematic of the supply chain sub-model showing relationships and information flows between market chain agents and value distribution.

Distribution of value and risk

The distribution of value of marine products has been recognised as an issue of concern in many developing country export fisheries, in terms of the percentage of final value accruing to agents along the chain and the under-pricing of resources (Jacinto, 2004). Even so, margins and value need to be considered in the context of risk borne by the respective agents along the market chain.

In the case of wild-caught fisheries, it has been suggested that fishers are usually poorly paid based on the final value of seafood products (Wood, 2001). Several factors give explanation for those receiving a relatively smaller percentage of final value. The remoteness of fishing grounds and small individual catches requires a middleman who can consolidate catches into sufficient quantities for transfer to exporters. Often these middlemen provide credit to fishers in the form of gear etc. to facilitate their fishing activities, although credit arrangements are usually not 'mutually beneficial'.

For export fisheries, financial risks increase as the product moves along the market chain. The middlemen and exporters bear mortality risks and the costs of holding fish post-harvest. The costs of transportation to markets are borne by middlemen, wholesalers and exporters and/or importers. Shipping and freight costs can make up between 50–65% of landed price paid by importer. At the consumption end of the chain retailers incur considerable rent and wage costs (MacFadyen *et al.*, 2003). The greater downstream risks of financial losses from mortality, prior to the product reaching consumer markets, partly explains the inequitable distribution of value.

Within the spreadsheet model, risk has been incorporated both for the fisher/fishing vessel and the supply chain sub-models. Within the fisher/fishing vessel sub-model, two types of risk have been accounted for: fish catches and fish prices. The first can account for increases or decreases in catches as a result of policy (management regulations) or environmental (overfishing) factors. The second recognises changes in demand that influence prices. Within the supply chain model, risk is associated with mortality, exchange rate fluctuations and downstream price expectations.

For each of the various risk components, an expected probability approach is used to calculate an expected value under a range of anticipated outcomes. These expected values are used in turn to generate a cumulative probability distribution (Figure 4b). In the case of the fishing operation, risk analysis models have been incorporated for price and catch. These are reflected in the annual returns to the vessel (Figure 3). For exporters and importers, it is intended that risk analysis will be incorporated in the form of estimating expected survival rates for a consignment of live fish. The cumulative probability distribution will likely be expressed in terms of both volume (quantity) and value of a consignment and also as an annual return based on the number of monthly or annual consignments.

(a)

Risk Analysis

Live Catch

	Kilograms	Probability					
Minimum	0	0.00					
Poor	6000	0.05	5% chance of getting between	0	and	6000	tonnes
Average	9000	0.20	15% chance of getting between	6000	and	9000	tonnes
Good	9500	0.60	40% chance of getting between	9000	and	9500	tonnes
Maximum	10,000	1.00	40% chance of getting between	9500	and	10,000	tonnes

Live Prices

	$	Probability					
Minimum	$25.00	0.00					
Poor	$30.00	0.25	25% chance of getting between	$25.00	and	$30.00	per kilogram
Average	$35.00	0.50	25% chance of getting between	$30.00	and	$35.00	per kilogram
Good	$40.00	0.75	50% chance of getting between	$35.00	and	$40.00	per kilogram
Maximum	$45.00	1.00	25% chance of getting between	$40.00	and	$45.00	per kilogram

FF Catch

	Kilograms	Probability					
Minimum	0	0.00					
Poor	2400	0.05	5% chance of getting between	0	and	2400	tonnes
Average	2600	0.20	15% chance of getting between	2400	and	2600	tonnes
Good	2800	0.60	40% chance of getting between	2600	and	2800	tonnes
Maximum	3000	1.00	40% chance of getting between	2800	and	3000	tonnes

FF Prices

	$	Probability					
Minimum	$7.00	0.00	1				
Poor	$7.50	0.25	25% chance of getting between	$7.00	and	$7.50	per kilogram
Average	$8.00	0.50	25% chance of getting between	$7.50	and	$8.00	per kilogram
Good	$8.50	0.75	25% chance of getting between	$8.00	and	$8.50	per kilogram
Maximum	$9.00	1.00	25% chance of getting between	$8.50	and	$9.00	per kilogram

(Press F9 to re-calculate)

Lowest return	$11,639
Highest Return	$124,086
Average Return	$75,419

Run Simulation

(b)

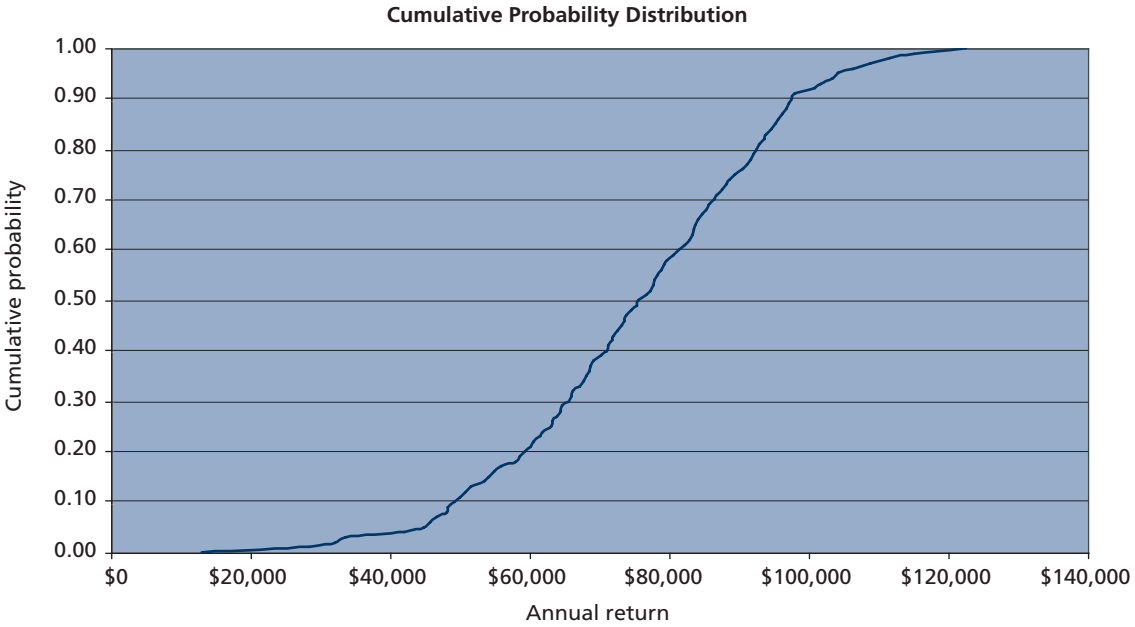

Figure 4. Risk analysis for fishing vessels which: (a) uses expected probabilities of a range of catch and fish price scenarios to estimate lowest, highest and average annual returns; and (b) generates a cumulative probability distribution of expected annual returns.

Conclusions

Despite the widespread use of market chain analysis as a means of identifying cost and revenue flows and value distribution for agents along the chain, idiosyncrasies of the LRFF trade constrain development of market chain models for use in identifying inefficiencies and distortions along the chain, in particular, inequities in value distribution.

Taking these limitations into account, this paper has outlined the initial development of an Excel™ spreadsheet that will be used to examine costs and revenues, and risks in the chain from the point of capture to the point of sale of LRFF.

Data limitations have dictated the form of the spreadsheet modelling approach, but in this first iteration, there are two models: for fishers and fishing vessel/middlemen; and for other agents in the chain. Adopting this approach is intended to overcome, to a degree, the lack of existing data on the operations of these downstream agents and also the need to collect the data required to populate the spreadsheet; data which will prove difficult to procure.

There are a number of next steps planned for this research. These will be to modify and expand on these initial spreadsheet models to:

- include and validate where possible, the economics and risk for both sea and air transport
- investigate trends in air transport that could lower mortality risks and assist more remote supplying countries (e.g. Pacific) to participate in the market for LRFF
- explore the impacts of policies that can improve market performance and distribution of product values. (Market structures in developing fisheries with complex market chains tend to be fixed so that reducing links in the market chain to the benefit of small-scale fishers will be difficult. Governance and distributional outcomes are often skewed toward wholesalers and exporters leading to marginalisation of small-scale fishers. Opportunities for horizontal cooperation are greater in aquaculture, where supply is more able to meet variant demand and farming cooperatives, have more control over their production and supply activities.)
- incorporate results from demand and supply modelling on the impacts of increased aquaculture production; most likely on beach prices for specific species or species groups.

Lastly, it is anticipated that, if there is sufficient data, spreadsheet models will be constructed not only for Australia but for at least two Southeast Asian countries and two Pacific countries. These models will aid capture fishery managers and the aquaculture sector in assessing future viability of the live reef capture and aquaculture fisheries within their countries.

References

Chan P.S.W. 2001. Wholesale and retail marketing aspects of the Hong Kong live seafood business. In B. Paust and A. Rice (eds). Proceedings of the second international conference: Marketing and shipping of live aquatic products. November 1999, Seattle. University of Alaska Sea Grant (AK-SG-01-03) pp 201–205).

Jacinto E.R. 2004. A research framework on value chain analysis in small scale fisheries. Paper presented to the 10th Biennial Conference of the International Association for Study of Common Property, Oaxaca, México, 9–13 August 2004. 27 pp.

MacFadyen G., Banks R, Banks R., Phillipps M., Haylor G., Mazaudier L. and Salz P. 2003. Background paper on the international seafood trade and poverty. Prepared under the EC-PREP project (EP/R03/014), 'International Seafood Trade: Supporting Sustainable Livelihoods among Poor Aquatic Resource Users in Asia'. Poseidon Aquatic Resource Management Ltd (UK), Network of Aquaculture Centres in Asia–Pacific and STREAM Initiative.

Sadovy Y.J. and Vincent A.C.J. 2002. Ecological issues and the trades in live reef fishes. In: P F. Sale (ed.) Coral reef fishes. Dynamics and diversity in a complex ecosystem. Academic Press, San Diego, pp 391–420.

Sadovy Y.J., Donaldson T.J., Graham T.R., McGilvray F., Muldoon G.J., Phillipps M.J., Rimmer M.A., Smith A. and Yeeting B. 2004. While stocks last: the live reef food fish trade. ABD Pacific Studies Series. Asian Development Bank, Manila.

van Anrooy R. 2003. Vertical cooperation and marketing efficiency in the aquaculture products marketing chain: A national perspective from Vietnam. Paper presented to the Aquamarkets 2003 Conference. Manila, Philippines 2–4 June 2003.

Wood E.M., 2001. Collection of coral reef fish for aquaria: global trade, conservation issues and management strategies. Marine Conservation Society, UK. 80 pp.

Wolfe S. 2002. Potential Benefits of Functional Foods and Nutraceuticals to the Agri-Food Industry in Canada. Final report submitted to Agriculture and Agri-Food Canada, Food Bureau, March 2002. Scott Wolfe Management. 76 pp.