

# The role of the Network of Aquaculture Centres in Asia-Pacific (NACA) in addressing food safety and trade issues in cultured seafood

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## Introduction

South-East Asia's average per capita supply of seafood is currently 24.7 kg a year. Maintaining this level for a projected population of 655 million by 2020 will require 16.2 million tonnes of food fish in the region. Assuming 30% continues to be contributed by aquaculture, almost 5 million tonnes of food fish will have to be supplied by culture in the region. The contribution of aquaculture to supply this demand indicates its increasingly significant and important role in the future.

Grouper, Asian sea bass, milkfish and snapper are the most popular marine finfish species cultured in the region. Marine finfish aquaculture in the region is diverse in terms of species being cultured, but still with generally low production and/or productivity. Except for milkfish, a large proportion of farmed marine finfish in the region is sold live, as it is one way to offset the high production cost (Pawiro 2006), and the live reef-fish food (LRFF) trade is becoming an important segment of trade in the region.

The Network of Aquaculture Centers in Asia-Pacific (NACA) is an intergovernmental network established through a United Nations Development Programme/Food and Agriculture Organization project in 1980. It became autonomous in 1990, and now has 17 member governments. The organisation supports the development of aquaculture in the Asia-Pacific region. Its objectives are: to increase the production of 'fish'; to improve rural income and employment; to diversify rural farm production; and to enhance foreign-exchange earnings and savings through aquaculture. These objectives are achieved through coordinated action programs implemented by a network of regional and national centres and associated institutions and agencies working together on the many issues of importance to regional aquaculture. Further information can be found at <[www.enaca.org](http://www.enaca.org)>.

## Market access and trade

Among the various issues related to aquaculture development in Asia, those related to market access and trade, and food-safety and quality issues are receiving increasing attention from the international community. Consumers throughout the world are becoming increasingly sensitised to food-safety issues, including those related to aquaculture products. Residuals of antibiotics such as chloramphenicol and nitrofurans have been a major concern in shrimp, for example. For LRFF, Hong Kong recently recorded contamination by malachite green in imported farm-raised groupers. In addition, ciguatera poisoning of wild-caught reef-fish has been a concern, with occasional contentious cases.

Traditionally, food safety has been concerned mainly with postharvest handling and processing, where various sanitary and phytosanitary (SPS) measures and hazard analysis and critical control point (HACCP) regulations have been introduced. However, attention is

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shifting to the production process in aquaculture, including inputs used, where they come from, and the way the farms and animals are managed (Phillips et al. 2004).

Ensuring environmental and social responsibility is also becoming another market-access issue, although many developing countries contend that such issues are being used as non-tariff barriers to trade. Recent efforts have therefore been geared towards addressing both technical and non-technical barriers to trade in aquaculture products. Because of the imperative to address poverty, however, there is concern about how compliance with the increasingly complex and stringent regulations and standards that are necessary to gain access to markets can benefit, or at least not harm or marginalise, the small and poorer producers. Most farms in Asia are small scale, which makes it difficult and costly for them to individually adopt the aquaculture practices that assure access to international markets (Bueno 2004).

## Responses to food safety and trade issues

To address food safety, trade and related issues, NACA members have asked the organisation to help in various ways. The following sections provide information on NACA's developing program on these issues.

### **Assistance with standard setting**

It is advantageous for countries to have (as far as possible) a harmonised set of principles and standards for trade in aquaculture products. In this connection, the Consortium on Shrimp Farming and the Environment developed a set of 'International principles for responsible shrimp farming' (FAO/NACA/WB/UNEP/WWF 2006) that were adopted by NACA governments, and are being further presented at the FAO Committee on Fisheries (COFI) Aquaculture Sub-committee in late 2006 for possible global adoption. The principles address the following matters: site selection, pond design, water management, stocking, feeding, health management, food safety and social equity. The set of principles aims to provide specific guidance for implementing the Code of Conduct for Responsible Fisheries and a basis for development of better management practices, and may also be used as the basis for certification standards. The draft principles are the product of global consensus among important players, including farmer groups, industries, governments, non-governmental organisations and international organisations. NACA has been asked, with other partners in the consortium, to move forward from shrimp to development of a set of principles for other commodities, including marine fish.

### **Strengthening capacities to comply with international standards**

Strengthening awareness and capacity building to address issues surrounding trade and aquaculture products are desirable because the traditional fisheries and aquaculture institutions are not yet well equipped to address these issues. Regarding food safety and aquatic animal health, Asian countries are moving towards strengthening implementation of SPS and HACCP measures in aquaculture products. The future growth of aquaculture will depend on the ability of countries and organisations to strengthen institutional capacity to develop and implement policies and regulations that are transparent and enforceable.

Following the recommendation of the NACA Governing Council meeting in 2005, a special regional program on 'Food safety and trade in aquaculture products' has been initiated by FAO, NACA and the Danish International Development Agency (DANIDA) to help NACA members build capacity for international trade and food safety in domestic aquaculture products. Preparations are being made towards organisation of a regional workshop during 2006 or 2007 to further enhance regional cooperation on this issue.

### **Finding ways to benefit fully from the market chain**

Market chains are becoming more vertically integrated, in line with a 'farm to plate' philosophy. Capacity building, technical assistance and innovative institutional structures will be essential to ensure small-scale producers can participate and benefit from such trends. The implications of traceability for the small-scale farmers and the service and input suppliers surrounding some aquaculture systems with a very fragmented input supply and trading system remains to be seen. At the same time, vertically integrated market chains may provide producers with more stable markets, and opportunities for funding from 'higher' in the chain to support costs of transition to better practices at the farm level.

### **Pro-poor trade approach**

NACA and the STREAM Initiative (Support to Regional Aquatic Resources Management) recently completed a project on 'International seafood trade: supporting sustainable livelihoods among poor aquatic resource users in Asia'. The outcomes from the project demonstrate that international trade in seafood products and the associated seafood market chains within Asian countries offer many opportunities for the inclusion of poor people and the improvement of their livelihoods. However, there is a low level of awareness of this key finding. The importance of the seafood trade needs to be much more widely appreciated, along with a greater awareness of the role it can play in poverty reduction (Macfadyen et al. 2005). Key recommendations for improved pro-poor trade in the Asia-Pacific region are given in Annex 1.

### **Promoting more effective international cooperation and sharing experiences**

To assist the region and promote further understanding and cooperation amongst trading partners, there is a need for further initiatives to bring countries together in Asia, and with major importing countries to discuss issues in, share experiences of and develop solutions to common problems (Phillips et al. 2004). Sharing information on market and trade in aquaculture products is repeatedly addressed in various workshops and there is a considerable opportunity and need to improve national regional and international cooperation to provide market information services (market intelligence) including information on food-safety standards and market trends and prices.

## **Asia Pacific Marine Finfish Aquaculture Network**

The Asia Pacific Marine Finfish Aquaculture Network (APMFAN) is an example of an institutional and people network with a well-structured coordinated research and development (R&D) program with a broad participation. It involves a wide range of stakeholders; farmers, traders, industry, government R&D workers, NGOs, and policy makers. It has an institutional base in NACA, and has received assistance from ACIAR, the Asia-Pacific Economic Cooperation (APEC) forum, industry and governments. APMFAN was initiated in 1998 at a meeting of grouper aquaculture researchers in Bangkok, Thailand to promote effective regional cooperation on grouper R&D. The program consists of technical, socioeconomic (including livelihoods, alternative employment opportunities), marketing, training and extension, and information components. To date, the network has encouraged several collaborative projects under the program topics (Box 1), including projects on markets and trade in the live reef-fish trade. One advantage of the networking approach is that it provides projects with access to a greater range of expertise and knowledge, as well as a broader geographic impact.

Interest in marine fish farming in Asia continues to grow, and this collaborative work program continues to expand, providing a comprehensive framework for collaboration in development of marine fish farming in the region. In addition, the recent NACA/FAO regional mariculture workshop held in Guangzhou (March 2006)<sup>2</sup> recommended that APMFAN be used as a model for further regional cooperation in mariculture development within the Asia-Pacific region.

**Box 1.** APMFAN program topics

1. Production technology
  - 1.1 Broodstock
  - 1.2 Larviculture
  - 1.3 Nursery
  - 1.4 Grow-out
  - 1.5 Post-harvest
2. Environment
3. Marketing
4. Food supply, certification
5. Socioeconomics, livelihoods
6. Fish health
7. Training and extension

Some recent highlights of APMFAN marketing program activities follow.

### **Certification of aquaculture products**

Certification of aquaculture products and eco-labelling are becoming increasingly important issues in seafood industries. Certification schemes are starting for several aquaculture products, but there is yet to be one for mariculture products in Asia, including live fish. A start has been made with an APEC-assisted Maine Aquarium Council-led development of 'International Standards for the Trade in Live Reef Food Fish', with APMFAN participants contributing to the aquaculture section (Annex 2). The principles for better management included in this project could provide a basis for certification standards, but the development of a workable certification *system* will take much longer.

### **Market analysis and studies**

A regional study on sea-farming and markets was completed in cooperation between the Thai Department of Fisheries and with support from the Terre des Hommes (TDH) Foundation, Italy. The study covered Indonesia, Malaysia, Hong Kong, China, Chinese Taipei and Thailand. To prepare for the FAO/NACA regional mariculture workshops, an analysis was conducted on the demand for mariculture products and major market issues constraining future growth of the sector. The outcome from this study fed into the development of the NACA/FAO regional mariculture workshop in Guangzhou, China.

### **Regional cooperation**

The network continues to support cooperation among countries, and also among stakeholders along the market chain. China-Malaysia cooperation in marine fish farming was also supported through several joint meetings in both countries, for exchange of technology and market information. A market study program was conducted by NACA, in cooperation with

<sup>2</sup> NACA/FAO regional mariculture workshop, 'The future of mariculture: a regional approach for responsible development of marine farming in the Asia-Pacific region', 7-11 March 2006, Guangzhou, China.

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the Guangdong Provincial Bureau of Ocean and Fisheries, Guangdong Fishery Society, Guangdong Dayawan Bay Mariculture Research and Development Centre (Department of Marine & Aquatic Products, China), and the Agriculture, Fisheries and conservation Department (AFCD)-Hong Kong SAR. This popular study program in 2005 explored seafood markets in Guangzhou, Dayawan, Shenzhen, Shanwei, Raoping and Hong Kong SAR, and introduced participants from producing countries to the demand side of the live marine seafood trade and the latest developments in marine fish farming and sea-farming in southern China, part of the world's biggest aquaculture producer and seafood market.

### **Information dissemination**

Information dissemination is successfully encouraged through linking researchers and institutions working on marine finfish aquaculture throughout the NACA network. The primary mechanism for information exchange has been a regular email newsletter and an electronic magazine that carries a summary of the latest research findings contributed by participants or collated by the NACA secretariat, and gives links to relevant websites and downloadable publications, and contact information. Market price information for high-value marine finfish in Hong Kong is a popular feature on the APMFAN website and is updated weekly. The recently concluded FAO/NACA mariculture workshop provided several new ideas on improving information dissemination on mariculture that will be followed up in the new NACA work program in 2006 and beyond.

## **Conclusions**

In order to gain international market access for aquaculture products, and successful trade, the aquaculture sector will have to give increasing attention to food safety and quality, as well as ensuring that the products are produced in an environmentally and socially responsible manner. NACA is supporting member governments and industries to develop and comply with international requirements and standards in various ways. Considering the realities of aquaculture and fisheries operations in Asian region, special caution and attention is required to small-scale farmers.

The live reef-fish food trade is faced with a wide range of issues in the Asia-Pacific region and NACA, specifically through the APMFAN, will continue to provide support and to encourage broad participation among various players, promoting collaboration with other initiatives with the aim of achieving sustainable mariculture development in the region.

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## Annex 1

A summarised version of key recommendations for improved pro-poor trade in the Asia-Pacific region (Macfadyen et al. 2005, cited in Gonzales et al. 2006)

1. The importance of trade in aquatic products needs to be more widely appreciated.
2. The capacity of fisheries departments should be developed on issues such as trade negotiations, promotion and extension.
3. Capacity in local-level organisations should be developed.
4. Traceability of products must be encouraged.
5. Development of fishery policy and trade policy must be participatory and include poor stakeholders and their representatives.
6. Support improved communications regarding international trade including raising awareness on the impacts of trade barriers.
7. Pro-poor trade policy implementation must be backed up by wider local management of resources and good governance initiatives.
8. Greater support for pro-poor trade research.
9. Establish preferential tariffs for socially certified products.
10. Focus on quality and reliability of supply.
11. Support detailed studies on the impacts of certification schemes and the potential of poor stakeholders to be marginalised by these needs to be recognised.
12. Governments and donors should work through NGOs and their associated networks to reach poor stakeholders.
13. Governments in Asia should examine whether parts of the international market chain can be encouraged to relocate to Asia.
14. Support the increased availability of micro-finance.
15. Complementary activities of those engaged in trade who remain poor should be investigated.
16. Occupational health and safety issues should be incorporated in any eventual certification schemes.

## Annex 2

The aquaculture section of the principles for better management under the 'International Standards for the Trade in Live Reef Food Fish'. A full document is available at: <[http://library.enaca.org/NACA-Publications/Marinefish\\_International\\_LRFFT\\_Standard.pdf](http://library.enaca.org/NACA-Publications/Marinefish_International_LRFFT_Standard.pdf)>.

### **3 Requirements for the aquaculture of live reef-fish as food**

#### **3.1 Management requirements**

##### *3.1.1 Use of hatchery reared fry and fingerlings*

- a) Preference shall be given to use of hatchery-reared fingerlings for LRFF aquaculture.
- b) Hatchery and nursery producers should use and promote the use of appropriate procedures for the selection of broodstock and the production of eggs, larvae and fry that lead to healthy and good quality fry and fingerlings.

##### *3.1.2 Limits to harvesting wild-caught fry, fingerlings and juveniles*

- a) The harvesting of wild-caught fry and fingerlings shall occur only when it can be demonstrated that it does not damage or negatively impact the sustainability of wild stocks.
- b) Aquaculture farms that use wild-caught fry, fingerlings and juvenile must have a program in place to eliminate their use for LRFF aquaculture.

##### *3.1.3 Compliance with national and international laws*

All participants engaged in LRFF aquaculture shall comply with the applicable laws of international, national, sub-national and local authorities.

#### **3.2 Operational requirements**

##### *3.2.1 Post-capture treatment of wild-caught larvae and juveniles*

Measures shall be taken to minimise post-capture mortality of wild-caught larvae and juveniles.

##### *3.2.2 Fish health management (including stock movements)*

Aquaculture farms shall adopt effective farm and fish health management practices that minimise risk of spread of fish pathogens.

##### *3.2.3 Aquaculture feed supply and management*

The protein used for fish feed shall be derived from a sustainable resource.

##### *3.2.4 Grow-out farms siting and habitat interactions*

Aquaculture farms should be sited so as to:

- a) maintain fish in optimum health
- b) minimise damage to habitats
- c) minimise interference with other coastal resource users.

##### *3.2.5 Harmful algal blooms*

Aquaculture farms shall have an action plan to deal with a local occurrence of harmful algal blooms.

##### *3.2.6 Chemical and drug use in aquaculture*

- a) Hazardous chemical inputs and drugs shall be used in a manner consistent with known best practices.
- b) Therapeutants, hormones, drugs, antibiotics and other disease-control chemicals shall be employed in a manner to ensure their safe, effective and minimal use.

##### *3.2.7 Waste control and effluent management*

Aquaculture farming shall be practised in ways that minimise the environmental impacts of waste.

##### *3.2.8 Food quality and safety*

Aquaculture farms shall ensure the food safety and quality of aquaculture products by promoting efforts that maintain product quality at the appropriate national and international standards. The standards shall apply before and during harvesting, during on-site processing, in storage and during transport of the products.

##### *3.2.9 Socioeconomic, gender and poverty issues*

Responsible aquaculture practices shall be adopted that support rural communities, involve women and marginalised groups, and contribute to poverty alleviation.

# The impact of mortality and price risk on costs and value distribution along the market chain for live reef-fish as food: a spreadsheet analysis

Geoffrey Muldoon<sup>1</sup> and Bill Johnston<sup>2</sup>

## Introduction

The perception that fisheries resources in developing countries are undervalued is widespread, particularly with respect to reef-based fisheries (Munro 1996; McManus 1996; Jacinto 2004). Internationally traded reef species, such as ornamental fishes and live reef-fish as food (LRFF) are high-value commodities and, in the case of LRFF, are considered to be luxury food items. In the case of the trades in reef species, it is widely held that fishers are being poorly paid relative to the final retail value of these products (Wood 2001; Sadovy et al. 2004). While often not in possession of good market information, the impression among suppliers (mainly fishers) in exporting countries is that the price they are receiving is too low (Sadovy 2005).

In response to the need to better understand the market for LRFF, a research project is being funded by the Australian Centre for International Agricultural Research (ACIAR)<sup>3</sup>. As part of this project, a market-chain analysis is being carried out to identify key risk and cost components of the market chain, in particular to enable comparison of risk-related returns among intermediaries (agents) from retailers to small-scale fishers and to address concerns over inequitable distribution of the value of LRFF products.

In low-technology, export-oriented fisheries with distant demand centres, such as the LRFF fisheries, the market chain must, by necessity, be quite extended (Muldoon and Johnston 2006). This translates to relatively high costs of transport and marketing (MacFadyen et al. 2003; Rola-Rubzen and Hardaker 2006). Because the commodity of interest is unusual in that it is a living commodity, in this study we are mainly concerned with risk of mortality of LRFF along the market chain and its impact on costs and revenues. Risk of mortality along the LRFF market chain will greatly affect costs and hence expected revenues of downstream agents, and will influence the prices they are prepared to pay to upstream agents. The price expectations among suppliers in exporting countries may not be realistic in the face of these mortality risks and their associated costs.

The purpose of this paper is to set out the means by which this exploration of costs and risk has been undertaken, in the context of equitable income distribution. The next section of the paper provides an overview of the costs, including capital, marketing and transportation costs, borne by various agents along the LRFF market chain. This is followed by a brief review of risks that confront market-chain agents and the likely distribution of risk along the market chain. We then describe the steps through the process of developing market-chain models for the LRFF trade. The first step in undertaking this component of the project was to describe the market chain for the LRFF trade. The next was to develop a supply-chain model

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<sup>3</sup> Project ADP/2002/105, 'Economic and market analysis of the live reef-fish food trade in the Asia-Pacific'.

to describe the distribution of net value and profit margins along the chain, based only on transport and marketing costs. The final stage in developing this model has been to ascribe risk profiles to the activities performed by the various chain agents in moving the product along the market chain. The last section of this paper summarises the work thus far and discusses expected future work.

## Classification of costs

Two types of costs are incurred by agents along the market chain for LRFF: capital costs and distribution costs. Capital and distribution costs vary both between the countries that supply LRFF and among the agents that comprise these discrete supply chains.

Capital costs for fishing operations range from between US\$700 and US\$2,000 in Indonesia and the Philippines, to a minimum of US\$100,000 in Australia (Padilla et al. 2003; Sadovy et al. 2004).<sup>4</sup> The large distances to export hubs and markets, and the need to retain the product alive, require the construction of sea- or land-based holding facilities by traders and exporters. Sea-cage construction costs range from US\$1,250 to US\$2,500 per unit<sup>5</sup> in Indonesia and the Philippines, while capitalisation of land-based holding facilities in exporting countries ranges from US\$10,000–US\$25,000 in Indonesia and the Philippines to more than US\$200,000 in Australia (Muldoon and Johnston 2006).<sup>6</sup> The main distribution costs incurred by downstream agents are the costs of holding and transporting LRFF to consumer markets in Hong Kong. Daily holding costs (i.e. wages, fish feed, electricity etc.) vary from US\$0.03–US\$0.05 per kilogram in supply countries of South-East Asia to approximately US\$5 per kilogram in Australia. Transport costs vary by mode of transport used (i.e. sea or air) and proximity to market, and range from US\$4.50–US\$5.00 per kilogram by sea from South-East Asia to US\$7.05–US\$8.80 per kilogram by air from Australia. The lower costs of shipping by air from major cities or export hubs in South-East Asia exclude internal transport costs by air or sea<sup>7</sup> (Table 1).

Overall, agents further along the market chain incur considerably higher capital and distribution costs than do the primary producers (fishers and middlemen) and, as such, they carry a considerably higher risk of loss of returns from mortality of the 'live' product as it traverses the market chain from primary producer to consumer markets.

## Risk and the distribution of value

Much of the literature on risk in the resource sector is agriculture-based and deals with effects of economic and environmental risk on yields and decision-making (Chambers and Quiggin 2004; Lien et al. 2004), impacts of price risk on production (Chavas and Holt 1996; Khumbhakar et al. 2002), and price and exchange risk in commodity markets (Newbery and Stiglitz 1979; Hinchy and Fisher 1988), including developing countries (Claessens and Duncan 1993). In the fisheries sector, risk studies have examined production risk and risk preferences in aquaculture (Tveteras 1999; Valderrama and Engle 2001; Kumbhakar and Tveteras 2003; Peterson et al. 2005), risk associated with assessment and management of fish stocks (Francis and Shotton 1997; Caddy 1999) and harvest or effort allocation strategies

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<sup>4</sup> Fishers usually receive financial assistance to undertake investment in capital equipment, with repayments deducted directly from their catch revenue until the loan is repaid.

<sup>5</sup> A 'unit' typically consists of four to six wells (see Bentley et al. 1999). Sea-cage holding facilities range in size from four up to 20 or more units.

<sup>6</sup> The capitalised value of land-based holding facilities in Hong Kong is not known but, given the high land prices there, would be expected to be considerable relative to South-East Asian exporting countries.

<sup>7</sup> See Muldoon and Johnston (2006) for a detailed breakdown of holding and transport costs.

designed to reduce risk (Holland and Sutinen 1999; Hilborn et al. 2001). Few studies deal with heterogeneous 'economic' or price risk encountered by agents along the market chain (Touzeau et al. 2000). In this study, we are concerned primarily with two types of risk; the impact of price risk on production and the risk of mortality as the live fish passes along the market chain and mortality's on the magnitude of financial losses incurred.

**Table 1.** Transport and operating costs, by transport mode, for the main export countries

Region/country	Operating costs (US\$/kg)		Transport costs (US\$/kg)	
	Broker	Exporter	Air	Sea
South-East Asia				
Indonesia	n/a	n/a	3.00–3.50	4.50–5.00 <sup>a</sup>
Philippines <sup>b</sup>	0.01	0.02	3.70–4.70	4.50–5.00 <sup>a</sup>
Malaysia	n/a	n/a	1.50–2.00	4.50–5.00 <sup>a</sup>
Vietnam <sup>b</sup>	0.03	0.05	~ 3.00	4.50–5.00 <sup>a</sup>
Oceania				
Australia	Not applicable	6.50	7.05 <sup>c</sup> / 8.80 <sup>d</sup>	n/o
Fiji Islands		n/a	n/o	6.00–7.00 <sup>e</sup>
Papua New Guinea		n/a	n/a	4.00–4.50 <sup>e</sup>
Indian Ocean		n/a	n/o	6.00–7.00 <sup>e</sup>
Seychelles		n/a	n/o	4.70–5.40 <sup>e</sup>
Maldives				

<sup>a</sup> Costs depend on quantity collected, fuel prices, and weather conditions affecting transportation times.

<sup>b</sup> Costs are daily costs per kilogram and include wages, fish food, and maintenance.

<sup>c</sup> Costs per kilogram by oxygenated bin (including cost of returning bin to source).

<sup>d</sup> Costs per kilogram by aerated bin (including cost of returning bin to source).

<sup>e</sup> Costs are based on a 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: Sadvoy et al. (2004)

Consideration of risk in the context of artisanal fisheries may not conform to traditional risk-aversion behaviour. With respect to fishing effort, previous studies have shown that fishers tend to be mostly risk-averse (Bockstael and Opaluch 1983; Dupont 1993; Eggert and Tveteras 2001). These results contrast with those from artisanal fisheries in South-East Asia where fish stocks tend to be more heavily exploited and catch rates are highly variable. Under these conditions, effort allocation of fishers tended not to be related to spatial patterns in fish abundance but rather to minimising risks through minimising operational costs (van Oostenbrugge et al. 2001; Pet-Soede et al. 2004). Moreover, the lack of alternative employment opportunities usually results in temporal allocation of fishing effort remaining constant throughout the year, regardless of fluctuations in prices (Pet-Soede et al. 2003). Price fluctuations in and of themselves, however, will affect fishery returns and need to be incorporated into any analysis of how value changes are distributed along the value chain.<sup>8</sup>

Within the LRFF fishery, supply of effort is likely to be highly inelastic because of its subsistence or artisanal nature. Target species of the LRFF trade have been heavily depleted in the region (mainly South-East Asia) and the fishery is operating well beyond maximum sustainable yield<sup>9</sup> and catch is thus also likely to be inelastic (Copes 1972). Fluctuations, or expected changes in beach price, would, in normal circumstances, influence fishing effort and hence catch rates, but the artisanal and subsistence nature of the fishery, coupled with a

<sup>8</sup> A 'value chain' is a description of the full range of activities required to bring a product through different stages of production, to delivery to consumers, and then disposal and the extent to which intermediaries/agents gain from participating in the chain (Kaplinsky and Morris 2003; Jacinto 2004).

<sup>9</sup> Many reef-based fisheries of South-East Asia are considered to be at the stage of 'Malthusian' over-fishing, in which immature fish form a large proportion of the total catch (Munro 1996).

highly over-exploited stock, suggests the impact of 'price' per se on production decisions will be minimal (Wohlgenant 2001).

That the product is living and the fishing grounds are remote from markets contribute to relatively high costs of distribution (transport and marketing) in the LRFF trade. For export fisheries in general, financial costs, and hence risks, increase as the product moves along the market chain. This is also the case for agents along the market chain for LRFF. The risk of most importance to LRFF trade agents will be that of product mortality. This is based on the assumption that a live fish has no alternative market if it dies, with the exception of the fisher who may be able to market his catch in fresh fish markets. In the case of fish mortality, the agent who is in possession of the LRFF at that time will suffer not only a loss of revenue but also incur per unit costs of transport and marketing.

The risks associated with the distribution of LRFF to consumer markets are interdependent. Poor handling and husbandry practices employed by upstream agents (fishers and middlemen) can increase the risk of mortalities occurring further along the chain as the fish passes to subsequent agents<sup>10</sup>. The agents further along the chain (exporters and wholesaler importers) may have limited ability to control the quality of the live product they purchase; other than through punitive measures or vertical integration. For these agents, whose exposure to financial loss from mortality is high relative to others, the goal may be one of maximising the reliability of an acceptable outcome (i.e. consistently low rates of mortality) as opposed to minimising mortality losses (Hardaker et al. 2004; Regan et al. 2005<sup>11</sup>). This point is elaborated upon in the 'Conclusions and future work' section of this paper.

The distribution of value gains from marine products is recognised as an issue of great concern in developing-country export fisheries. As a high-value commodity there is a perceived potential for high economic gains along the market chain for LRFF. Value and profit margins need to be considered, however, in the context of costs incurred and risk borne by the respective agents along the market chain. Risk of fish mortality is usually not factored into the costs of transportation or the distribution of wealth among stakeholders. Mortality remains a major factor, however, in the cost of delivering LRFF to markets to Hong Kong, with most fish deaths occurring during the holding phase in the source country and the transshipment phase. This may explain any inequitable distribution of value among agents along the market chain.

## The market chain for live reef-fish as food

### Conceptual market chain

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.

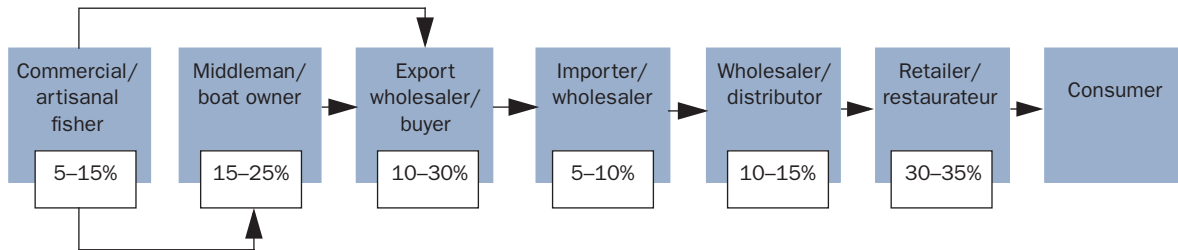
The LRFF trade is a secretive and collusive industry and, as a consequence, information on costs and revenue data with which to populate the market chain were difficult to obtain. Costs that could be collected included, but were not limited to, the operational costs for fishers and, where relevant, fishing-vessel owners; the costs of holding fish either directly for export or for transshipment to the next producer-country agent in the market chain; and the costs of transporting LRFF by air or sea. Value-added prices (sale price minus marketing and

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<sup>10</sup> For example, fish health may deteriorate during holding in sea-cages due to poor water quality, poor diet, a lack of disease prevention efforts, overcrowding etc

<sup>11</sup> Regan et al. (2005) suggest that the best strategy is 'one that satisfies us with an outcome that is both "good enough" and that makes us as immune as possible from unacceptable outcomes'.

transport costs) paid were collated for as many of the chain agents as was possible, as these are means by which to measure income distribution (Kaplinsky and Morris 2003). A hypothetical market chain comprising only on transport and marketing costs is shown in Figure 1. From these data two initial spreadsheet-based models were developed, the fisher model and the supply-chain model.



**Figure 1.** Hypothetical economic value chain model for wild-caught live reef-fish for food. The percentage represents the estimated proportion of total value-added retained by the intermediary at that part of the market chain.

### Fishing-operation model

A model of the fishing operation was developed using data from the Australian reef-line fishery. This fisher sub-model allows for costs to be derived using effort parameters and total revenues to be derived using catch parameters<sup>12</sup> (Muldoon and Johnston 2005a). In this model, total revenues are comprised of sales of frozen and live catch, with catch comprising two 'commodities'—coral trout and all other species. The model accounts for both fixed and variable costs of fishing. 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.

Within the fisher model, two types of risk have been accounted for: fish catches and fish prices. These risks have been incorporated into the fisher model through the use of cumulative probability distributions around an average catch and price, both of which are determined from user-defined parameters. Empirical data have been used for the purposes of this study to define probability intervals for price and catch with probability intervals for annual catch based on the activity and throughput of a 'representative' vessel within the fleet (Muldoon, unpublished data). Price and catch intervals have been arbitrarily defined into five categories: minimum, poor, average, good and maximum (Figure 2). The reef-line fishery on the Great Barrier Reef became a quota-based fishery in July 2004 and so maximum catch for any fishing operation will be the individual quota it has been allocated.

These price and catch data have been used to derive a cumulative probability distribution of annual net returns after costs (including, where appropriate, an imputed skipper wage for owner-operators), showing lowest, highest and average returns (Figure 3).

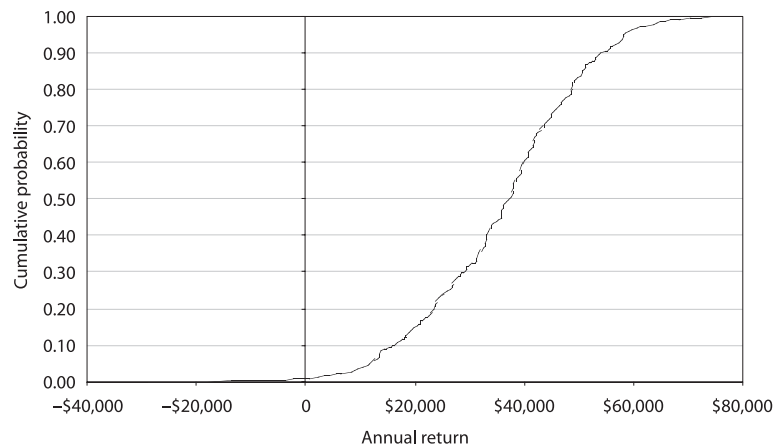
It is important to recognise that the structure of supply in Australia, which has been used to define this model, differs markedly from that for South-East Asia and the Pacific. In Australia, large fishing vessels support a number of fishers, with these fishers being paid on the basis of individual catch, while the boat owner is responsible for all other variable and fixed fishing costs. In South-East Asia, while there are some larger fishing boats supporting multiple fishers, the majority of fishers are single-person operations. Furthermore, fishers in

<sup>12</sup> For the fisher sub-model, revenues can be based on either empirical beach prices or using a margin-based approach, again using empirical evidence. Beach prices can also be used to derive margins based on costs.

Australia face no fishing costs while fishers in South-East Asia do incur costs either directly or indirectly through debt repayments to financiers and middlemen. Although the trade in the Pacific has been operating irregularly for several years, the normal arrangements are for local fishers to work directly for the fish exporter, who supplies the fishing platform and fishing gear (lines, bait, hooks) with the fisher receiving a 'net' return for fish caught.

		Kilograms	Probability				
<b>Live Catch</b>	Minimum	0	0.00				
	Poor	6,000	0.05	5% chance of getting between	0	and	6,000 kilograms
	Average	7,225	0.40	35% chance of getting between	6,000	and	7,225 kilograms
	Good	8,500	0.80	40% chance of getting between	7,225	and	8,500 kilograms
	Maximum	9,000	1.00	20% chance of getting between	8,500	and	9,000 kilograms
<b>Live Prices</b>	Minimum	\$25.00	0.00				
	Poor	\$30.00	0.10	10% chance of getting between	\$25.00	and	\$30.00 per kilogram
	Average	\$34.61	0.60	50% chance of getting between	\$30.00	and	\$34.61 per kilogram
	Good	\$37.50	0.95	35% chance of getting between	\$34.61	and	\$37.50 per kilogram
	Maximum	\$40.00	1.00	5% chance of getting between	\$37.50	and	\$40.00 per kilogram
<b>FF Catch</b>	Minimum	0	0.00				
	Poor	3,000	0.05	5% chance of getting between	0	and	3,000 kilograms
	Average	4,603	0.40	35% chance of getting between	3,000	and	4,603 kilograms
	Good	5,000	0.80	40% chance of getting between	4,603	and	5,000 kilograms
	Maximum	5,500	1.00	20% chance of getting between	5,000	and	5,500 kilograms
<b>FF Prices</b>	Minimum	\$7.00	0.00				
	Poor	\$7.50	0.25	25% chance of getting between	\$7.00	and	\$7.50 per kilogram
	Average	\$7.95	0.50	25% chance of getting between	\$7.50	and	\$7.95 per kilogram
	Good	\$8.50	0.75	25% chance of getting between	\$7.95	and	\$8.50 per kilogram
	Maximum	\$9.00	1.00	25% chance of getting between	\$8.50	and	\$9.00 per kilogram

**Figure 2.** Expected catch and price for a 'representative' fishing vessel fishing in the Queensland, Australia, reef-line fishery



**Figure 3.** Cumulative probability distribution of annual net returns for a 'representative' vessel fishing in the Queensland, Australia, reef-line fishery

### Supply-chain model

The first step in enabling comparison of returns to small-scale fishers is developing a model of the distribution of value-added along the supply chain. As before, the paucity of data on costs incurred by the various agents and agents has confounded the development of this model. In recognition of this lack of data, a simplified model has been developed that incorporates wholesaler/exporter, importer/distributor and retailer. Current margins are based on limited empirical evidence, with these margins adjustable to enable exploration of

their impacts on returns to agents and to aid in examining the issue of 'fair price'. There are two approaches to deriving what constitutes a fair economic return:

- 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
- a top-down approach deriving a distribution of the final product value between agents using information that draws on known costs of transport and marketing and that conforms with our knowledge of profit margins along the chain.

Developing a bottom-up market chain model for the LRFF fishery is problematic for two related reasons. Firstly, there is, with few exceptions, a paucity of usable data 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.

This supply-chain model uses a simplified top-down approach incorporating wholesaler/exporter, importer/distributor and retailer. A cumulative probability distribution of time-series data on wholesale and retail prices in Hong Kong (International Marinelife Alliance, unpublished data) was used to determine the conservative 'average' price (i.e. this price occurs on average at least 50% of the time) for use in the model. The starting point for the model can be either the restaurateur (i.e. retail price) or the importer (i.e. wholesale price). Available empirical evidence on transport and marketing costs and value-added revenues were used to work backwards and establish 'credible' initial values and profit margins. These results have been compared against known costs of fishing operations, to establish their veracity. This model can be used to explore the impacts of cost and revenue changes on the distribution of the final value among agents along the market chain in the form of 'margin' returns accruing to agents along the market chain.

This supply-chain model was based on transport and marketing costs only. It was recognised that further refinement of the model was needed to incorporate the consequence of risk on these costs and revenues, and to allow for exploration of the issue of 'fair price'.

### **Supply-chain models incorporating risk**

The primary objective of this project component was to measure risk components of the market chain in terms of impacts on costs and hence margins of the various agents. Risk has been incorporated into the supply-chain model using the Monte Carlo sampling techniques. Monte Carlo sampling is entirely random, such that any given sample may fall anywhere within a range of the designated input distribution.

The starting point for the model was the fishing trip. The Monte Carlo approach was used to derive a sample catch with this 'sampled' catch becoming the consignment of LRFF that passes between the agents along the market chain. All agents, including the fisher, are assumed to face one of two types of risk in this model: price risk and mortality risk. In addition, the importer/wholesaler is assumed to face an exchange rate risk, but this is excluded from the present model. While it is assumed that price risk will pass through the model in a consistent manner, the types of mortality risk and their consequences will vary across agents (Table 2).

For each of the various risk components (price and mortality), a Monte Carlo simulation is used to calculate a cumulative probability distribution. The initial sample catch of the fisher/boat-owner is the maximum volume (kilograms) of LRFF that can be purchased by the exporter. Time-series data on beach prices<sup>13</sup> in supply countries, and on wholesale and retail

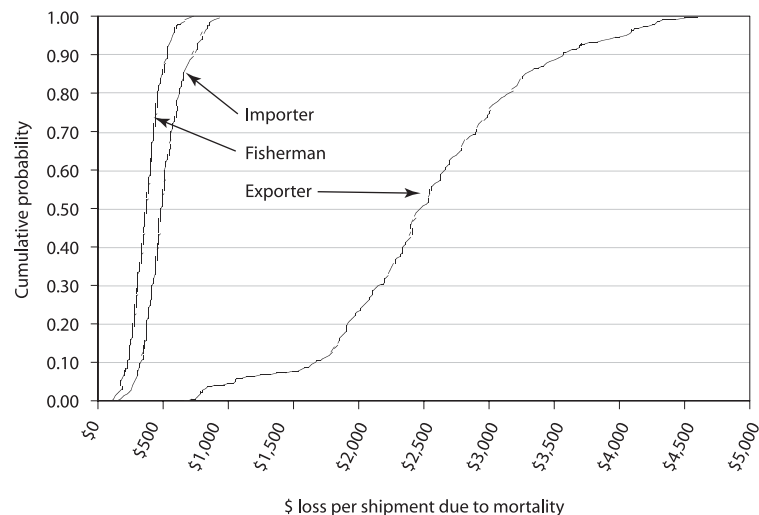
<sup>13</sup> The beach price refers to the amount paid by the buyer for a fish when it reaches shore, before export.

prices in Hong Kong, are used to calculate a probabilistic distribution of price for exporters, wholesalers and importers and to generate a 'sample' revenue, without mortality risk, for that consignment (Muldoon, unpublished data; International Marinelife Alliance, unpublished data). Mortality can occur at each stage of the market chain with the effect that the initial consignment volume would decrease cumulatively as it moves from one agent to the next. Monte Carlo simulation is used to quantify the number of mortalities in the sample shipment and, based on these mortality estimates, to calculate a cumulative probability distribution of diminished sample revenue and the average financial loss for each of the agents (Figure 4).<sup>14</sup>

**Table 2.** Mortality risks faced by intermediaries along the LRFF market chain

Risk faced	Fisher/boat-owner	Exporter	Importer
Barotrauma	✓		
Capture damage	✓		
Low oxygen	✓	✓	✓
Water quality issues	✓	✓	✓
Handling stress	✓	✓	✓
Transport damage		✓	✓

As noted previously, the asymmetric distribution of value needs to be considered in the context of variant costs and risk, specifically mortality risk borne by each agent. The transport and marketing costs borne by downstream agents are considerable in comparison to fishers (Chan 2001; MacFadyen et al. 2003) while, depending on the mode of transport used (sea or air), mortality risk during the post-capture husbandry and transshipment phase will also be higher than that faced by fisher/boat-owners (Sadovy and Vincent 2002). Consequently, the financial risks associated with mortality are magnified as LRFF move along the market chain.



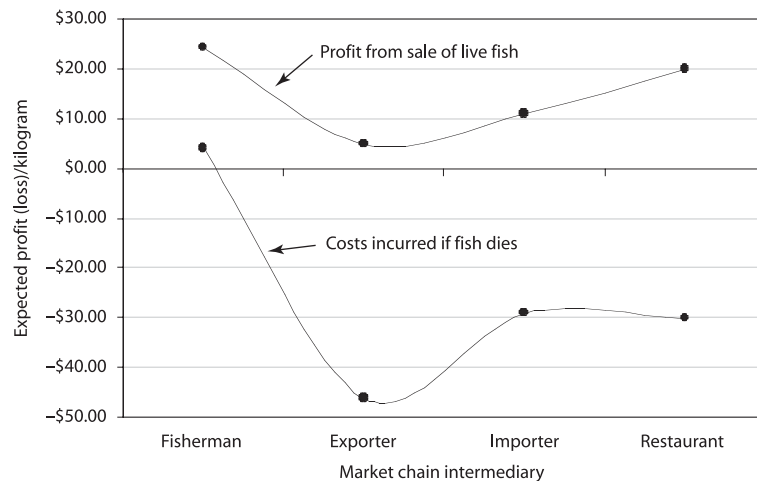
**Figure 4.** Cumulative probability function of potential loss per shipment of live coral trout, based on stated mortality risks faced by the market chain intermediary

The model recognises that the potential financial losses from mortality will be relatively lower for the fisher/boat-owner because, unlike exporters and importers, they can sell a fish intended for the LRFF market into fresh markets, albeit for a lower price, in the event that fish dies. Results from this preliminary 'risk-based' supply-chain model show that exporters

<sup>14</sup> The Monte Carlo simulation comprises 100 simulations.

face the highest potential financial losses, while fisher/boat-owners and importers face a similar but much lower potential loss (Figure 5).

These greater downstream risks of financial losses from mortality, before the product reaches consumer markets, can explain the existence of inequitable distribution of value.



**Figure 5.** Expected profit (loss) per kilogram of live coral trout based on expected price from the sale of live fish and losses incurred through transport and distribution costs by market chain intermediaries. Prices and costs are based on a 1 kilogram fish.

## Conclusions and future work

Live reef-fish for food 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. The models described in this paper represent the first step in understanding the LRFF market chain in terms of relative margins accruing to upstream (supplier) and downstream (demand) agents, and to evaluate the perception that value gains are being distributed inequitably.

With the extended market chains, the gains at each point along the chain will tend 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, use of low technologies, remoteness of fishing grounds and distribution of risk.

In terms of the asymmetric costs and risk being borne by agents along the chain, it may be that fishers are being fairly compensated but further work is required on several fronts to:

- extend the analysis to incorporate market chains in the Pacific and South-East Asia
- refine the model to account for greater magnitude in the risk of mortality and variant rates of mortality encountered over a larger number of successive shipments
- evaluate alternative transport technologies that generate different average mortalities but where one technology is more costly.

Efforts are underway to collate data from Indonesia and Papua New Guinea to be used in developing a fisher sub-model and a supply-chain model for those countries. The current model uses a unique estimate of price and mortality for one shipment to generate a single revenue outcome, both with and without mortality risk. This approach could be refined to

more realistically account for both the stochastic nature of mortalities and the seasonal nature of prices. In actuality, mortality may vary from less than 1% to 100%, and prices of LRFF have distinct seasonal patterns. A more realistic approach to account for our uncertainty parameter (risk) would be to use a nested probability approach that captures both the probability of mortality during a single shipment and the spectrum of mortality probabilities across multiple shipments ( $n = 200$ ) to generate an average mortality over, say, a fiscal year.

While a large volume of annual imports are still transhipped from exporting countries to Hong Kong via special-purpose, live transport vessels, about 60% of all LRFF imported into Hong Kong now arrive by air (Sadovy et al. 2004). Modes of air transport differ widely, ranging from oxygenated plastic bags packed in polystyrene boxes (in use throughout most of South-East Asia), to the large, moulded plastic, aerated or oxygenated bins, used by Australian exporters. These transport bins have several advantages over polystyrene boxes in that they can hold substantially more fish for longer periods and facilitate lower mortality rates (< 5%). Use of these transport bins does, however, introduce logistical problems, such as the return of bins to port of origin (polystyrene boxes are disposed of after use), and generates additional maintenance and operational costs. The market chain models we have developed for the LRFF trade could be used to contrast risk and revenue outcomes under these different technologies with their different cost structures.

While the distribution of value of marine products is recognised as an issue of great concern in developing-country export fisheries, another key issue is the under-pricing of resources. While it may be that costs and risks are being shared disproportionately, leading to compensatory value gains, there is a strong argument that the resources being extracted are being 'under-priced' (McManus 1996; Cesar et al. 2000; Sadovy 2005). Ideally, final consumer prices should reflect true costs of fish catches in terms of externality costs imposed on communities from over-exploitation of their resources (Jacinto 2004). It would be useful to examine ways to include environmental costs in these spreadsheet models as an additional variable for determining a 'fair price' to fishers.

It is anticipated that these spreadsheet models can be used in one of three ways:

- *negotiation*—producer countries can determine what is a 'fair' market price for live reef-fish for use in negotiating price arrangements with buyers and/or exporters
- *education*—inform suppliers of LRFF of the different costs and risk borne by various agents along the market chain that contribute to existing price structure
- *technology*—quantify how the adoption of new technology or best practices may reduce costs and/or risks, and the flow of benefits arising from these new technologies.

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# Production and marketing of live reef-fish for food in Indonesia

Sonny Koeshendrajana<sup>1</sup>

## Introduction

The live reef-fish food trade (LRFFT) has been becoming a significant economic activity in the Asia-Pacific with more than 20 countries supplying a market with an estimated product value of US\$350 million per year. The species constitute one of the most valuable and readily available fish export commodities produced by small-scale coral reef fishers in many sites throughout Indonesia. The main market for this product is the East Asian countries, particularly Hong Kong and the People's Republic of China generally. The LRFFT may be able to create economic potential for emerging societies, but it may also cause a tremendous threat to the sustainability of the particular resource. This can be viewed in terms of encouraging more fishers to go fishing intensively and attracting small-scale fishers to use powerful fishing units or even use illegal fishing devices that lead to serious problems. The problems were identified as destruction of coral reef habitat due to the use of explosive materials (bombs) and cyanide to capture the targeted live grouper species. This, in turn, causes decline of target fish stock and so sustainability of the fish trade.

To overcome the above problems, numerous strategic plans and actions have been initiated and implemented in Indonesia; for example, regulating the use of cyanide, banning the use of explosive fishing devices, advocating responsible practices in fishing and promoting alternative activity related to grouper production in the form of aquaculture. However, those efforts have yet to meet with success in the sense that what are essentially features of an unregulated fishery still occur. Following this frame of thought, research on the 'economic and market analysis of the live reef food fish trade' was conducted. Four areas of study were focused on during the research, namely fish supply, demand, trade and policy. Fish supply and demand were reviewed based on available secondary data of the country, consisting of the status and problems of that particular fish species. A means of verifying the data obtained was used. Marketing studies of the LRFFT were conducted, emphasising the marketing or supply-chain analysis.

## Objectives

Although serious problems occurred in the grouper industry, relatively little was known about the state of production and marketing of LRFFT in Indonesia. Therefore, the primary objective of this paper is to provide the identified production structure and marketing of LRFFT in Indonesia. The studies analyse economic importance of the production source and economic value of supply chain (marketing) of the LRFF from different production centres of the species in Indonesia.

## Scope of study

The study began by gathering all possible information related to the LRFFT. A National Research Priority Strategic (Riset Unggulan Strategi Nasional, RUSNAS) for grouper fish was

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initially approached to get the broader perspective of area covered and disciplines in grouper research. This was followed by discussion with the key players working on grouper fisheries. During the discussions, the suggestion was made to visit the existing grouper production centres representing both the capture and aquaculture industries, i.e. South Sulawesi, Bali, Lampung and Batam. Areas of study were identified in terms of production structure and marketing of the grouper.

## Approach

The studies were carried out in the following format. An intensive literature search related to grouper fisheries was carried out and examined drawing on the resources of many different institutions, such as universities, research institutions, the Agency for Assessment and Applied Technology (Badan Pengkajian dan Penerapan Technology, BPPT), national and provincial marine and fisheries services and the Central Bureau of Statistics (Badan Pusat Statistik, BPS). Surveys were conducted to verify the data gathered from the above institutions. The survey was also intended to obtain current data and information related to the focus of the studies.

## Data and source of data

Secondary and primary data were collected during the studies. Secondary data were based on the scientific papers and documents from the universities and research institutions, proceedings of workshops and statistics data provided by the Department of Marine Affairs and Fisheries and the Central Bureau of Statistics. Primary data were collected from the selected production centres of grouper. A quick survey was conducted in the selected sites. Several key respondents were interviewed during the surveys.

## Analysis and interpretation

Analysis and interpretation were carried out for each of the study sites, focusing on the production structures and their economic performance, and marketing of grouper. A cost-return analysis was applied to represent relative economic performance of each production structure. A supply-chain analysis was used to represent marketing and trade aspects of the species.

## Results and discussion

### **Production structure of grouper fishery**

The supply of grouper to the market is predominantly (86–93%) from capture fisheries. Although aquaculture contributes only a relatively small amount (4–14%), its contribution to the total shows a gradual increase from 1999 to 2005 (Table 1). This phenomenon may be attributed to the development of technological know-how of grouper which was widely introduced by government and practised by fish farmers.

Statistics data as in Figure 1 show that the grouper production trend from capture activity can be traced back to the year 1975, but grouper production data from aquaculture was available only from 1999. Figure 1 implicitly tells us that a significant development in aquaculture technology on grouper has been successfully obtained in the late 1990s. It may also imply that government moves to work on grouper culture started during that particular period.

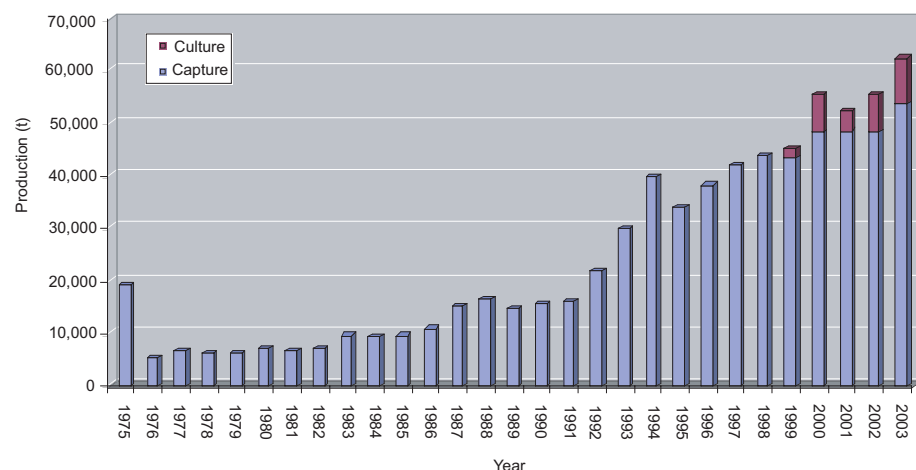
**Table 1.** Supply or production structure of grouper in Indonesia, 1999–2003

No.	Category	Production (t)					Average change <sup>a</sup> (%)
		1999	2000	2001	2002	2003	
1.	Aquaculture	1,759 (3.89)	6,879 (12.44)	3,820 (7.30)	7,057 (12.73)	8,638 (13.85)	14.63
2.	Capture	43,472 (96.11)	48,422 (87.56)	48,516 (92.70)	48,400 (87.27)	53,743 (86.15)	5.03
	Total	45,231	55,301	52,336	55,457	62,381	7.32

Source: Directorate General of Aquaculture (2005); Directorate General of Capture Fisheries (2005)

<sup>a</sup> Calculated from  $\sum_{i=1}^n [(Year_i - Year_{i-1}) / Year_{i-1}] / n - 1$ ;  $n$  is number of year.

Two types of grouper fish production existed, i.e. live grouper and fresh grouper. Unfortunately, division of these types of grouper fishing was not available in the national, provincial or even district fisheries statistics data. However, literature studies and surveys during January–December 2005 indicated that production centres for live grouper were widely distributed throughout Indonesia, as indicated in Table 2.



**Figure 1.** Trends in grouper production in Indonesia, from capture and culture fisheries, 1975–2003

## Production economics of live grouper fisheries

### *The capture fisheries*

Grouper fishing is considered as open-access. In open-access fisheries, i.e. those with little or no restrictions on who can fish, unemployed people tend to enter the fishery until the open-access equilibrium is met. Using the Gordon-Schaefer model (Anderson 1986; Conrad and Clark 1987), the equilibrium can be simply defined as the point at which total cost of fishing equals sustained yield. In the systems where there is an excess labour force and no reasonable alternative employment, the open-access equilibrium is the point at which the average fisher does not make a profit. If there is an opportunity cost, then this raises the cost line and equilibrium point to where the average fisher earns about the same as those who get benefit of the alternative livelihood.

Grouper fishing in Indonesia is practised by fishers in both western and eastern part of Indonesia (Table 2). Although grouper fishing has operated in the western part of Indonesia, such as west Sumatra (Indian Ocean), *Kepulauan Riau* (South China Sea) and *Kepulauan Seribu* north of DKI Jakarta, current studies indicate that the most intensive LRFF exploitation occurs

in the eastern part of Indonesia, employing legal standard of fishing unit and illegal fishing devices. Among those fishing grounds, South Sulawesi is considered the most important one due to the richness of its coral-reef ecosystem. This type of ecosystem is the habitat of the grouper. With the practice of non-responsible fishing activity, it may lead to degradation of the quality of coral reefs in that particular resource. In line with the above feature, verification of the data on grouper fishing was conducted in South Sulawesi province.

**Table 2.** Production centres—capture fisheries and aquaculture—for live-grouper in Indonesia, 2005

Activity	Region	District or site
Capture	Western part of Indonesia: NAD North Sumatra West Sumatra Bangka Belitung Riau Central Java East Java	Semelue Belawan, Sibolga and Nias Mentyawai and Bayur bay Kepulauan Bangka and Belitung Tanjung Pinang, Temiyang, Batam, Natuna Kepulauan Karimun Java Sapudi and Kangean
	Eastern part of Indonesia: East Kalimantan North Sulawesi Central Sulawesi South Sulawesi Southeast Sulawesi West Nusa Tenggara East Nusa Tenggara Maluku Papua	Samarinda and Balikpapan waters Minahasa, Gorontalo and Sangir Talaud Kepulauan Bangai and Togeau Makasar, Selayar, Bonerate, teluk Bone, Takalar, Spermonde and Sinjai Buton and Kendari Ekas and Saleh bay Flores, Komodo, Sumba and Timor Aru and Kei, Halmahera, Ceram and Banda Tual, Biak, Padaido and Cendrawasih bay
Aquaculture	Western part of Indonesia: Riau Lampung East Java Bali	Batam (Batam, Rempang dan Galang), Natuna Padang Cermin Northcoast close to Madura Gondol
	Eastern part of Indonesia: South Sulawesi NTB NTT	

Source: Verified from various sources, including DGAF (2005), DGCF (2005), Aliah et al. (2003), Anon. (2003, 2004).

In general, many studies have pointed out that fishers for grouper are small-scale fishers, characterised as follows: (1) fishers are very poor, as is often obvious from their clothing and the state of their houses; (2) fishers have been poor for at least a few years, to account for natural variations in the fishery; (3) there are no reasonable alternative livelihoods for the fishers; (4) there is no social welfare or unemployment system.

Many different types of fishing gear are used by South Sulawesi fishers to catch grouper, but the two most important and widely used<sup>2</sup> methods are the fish trap (*bubu*) and hook and line (*pancing*). During 1989 to 2003, total production, effort and catch per unit of effort (CPUE) generated by these fishing units are presented in Table 3. Fishing cost paid by fishers using two types of hook-and-line fishing are presented in Table 4.

#### *The aquaculture fisheries*

Initially, grouper culture was operated using natural or wild seed-stock collected by fishers. The fish farmers grow-out the fish by feeding it trash fish. Fortunately, recent developments in broodstock management and breeding technology have enable the production of seed.

<sup>2</sup> Similar case were reported by Sari (2006) and indicated by fisheries statistics data of each district in which coral reef ecosystems existed.

However, feeding grouper still depends on trash fish. The following subsection looks at typical financial performance of grouper culture in South Sulawesi, Bali, Lampung and Batam.

One cage unit is composed of 10 holes 2 × 2 m. The life-span of the cages ranges from 3 to 8 years with an average of 5 years. The price of trash fish and artificial feed used to feed the fish ranges from IDR<sup>1</sup> 3,000 to IDR6,000 and from IDR8,500 to IDR12,000 per kg, respectively.

**Table 3.** Grouper production, fishing effort and catch per unit effort (CPUE) of trap and hook-and-line fishing units in South Sulawesi, Indonesia, 1989–2003

Year	Production (t)		Effort (day fishing)		CPUE	
	Trap	Hook and line	Trap	Hook and line	Trap	Hook and line
1989	243.8	693.0	97,696	1,273,526	0.002495	0.000544
1990	194.7	672.7	72,403	1,199,758	0.002689	0.000561
1991	222.6	667.0	87,531	1,136,121	0.002543	0.000587
1992	307.4	711.4	98,106	1,174,477	0.003133	0.000606
1993	221.4	658.3	81,623	1,126,410	0.002712	0.000584
1994	219.1	901.7	72,083	1,224,049	0.003040	0.000737
1995	227.7	1,449.0	67,034	1,233,358	0.003397	0.001175
1996	282.9	1,369.0	72,179	1,162,890	0.003919	0.001177
1997	252.3	936.9	63,685	1,047,741	0.003962	0.000894
1998	237.9	1,159.4	47,083	1,024,425	0.005053	0.001132
1999	272.9	1,312.1	51,193	1,009,892	0.005331	0.001299
2000	156.6	1,186.7	34,903	931,080	0.004487	0.001275
2001	157.4	1,134.3	31,360	737,833	0.005019	0.001537
2002	121.8	1,348.5	39,847	826,651	0.003057	0.001631
2003	154.4	1,134.3	42,901	850,665	0.003599	0.001333

**Table 4.** Cost of fishing using two types hook-and-line fishing in waters of South Sulawesi, Indonesia, 2005

No.	Category	Cost of fishing (Indonesian rupiah/trip)			
		Hook and line, type I		Hook and line, type II	
1	Ice	158,500	6.02	596,000	14.86
2	Fuel	523,200	19.88	842,800	21.01
3	Engine oil	30,000	1.14	12,000	0.30
4	Bait	440,000	16.72	1,080,000	26.93
5	Food	1,480,000	56.24	1,480,000	36.90
	Total	2,631,700		4,010,800	

Notes: One trip is one day's fishing.  
Fishers operate 26 trips per month for 10 months of the year.  
For hook-and-line fishing type I, the number of crew per boat is 60.  
For hook-and-line fishing type II, number of crew per boat is 24.

The prices of *Kerapu Bebek* (humpback grouper) and *Kerapu Macan* (tiger grouper) are in the ranges IDR200,000–IDR250,000 and IDR45,000–IDR80,000 per kg, respectively. The stocking density was 3,000 × 10 g fry per hole for both the *Kerapu Bebek* and *Kerapu Macan* at a cost of IDR12,500 for *Kerapu Bebek* and IDR 8,000 for *Kerapu Macan*. The feed-conversion ratios for artificial feed and trash fish for *Kerapu Bebek* were 3 and 8; while for *Kerapu Macan* they were 4 and 7. These figures confirm those of Anon. (2005) who reported that the use of trash fish in the grouper grow-out industry gave food conversion ratio in the range 8–15: 1. Average mortalities during the grow-out operation were 50% and 60% for *Kerapu Bebek* (humpback grouper) and *Kerapu Macan* (tiger grouper), respectively. Given all the above information, the calculated financial analysis for both species in South Sulawesi is presented in Tables 5 and 6.

In Bali, production of tiger grouper in floating cages showed better performance with commercial pellet feed than with trash fish. Although in terms of operating cost the use of commercial feed was higher than the use of trash fish, the first treatment provided lower

<sup>1</sup> IDR = Indonesian rupiah.

mortality rate than the latter. Overall financial performances, in terms of the return:cost ratio, profit and payback period given by each treatment indicated that the use of commercial feed was better than trash fish, as presented in Table 7.

**Table 5.** Typical investment, costs and returns from *Kerapu Bebek* (humpback grouper, *Cromileptes altivelis*) aquaculture in South Sulawesi, Indonesia, 2005

	Artificial feed		Trash-fish feed	
	Value (IDR <sup>a</sup> )	(%)	Value (IDR)	(%)
Investment	31,000,000		31,000,000	
• 1 unit of cages (floating, wood) 16 × 10 m (10 cages of 2 × 2 m)	10,000,000		10,000,000	
• Nets, 20 units of 2 × 2 × 3 m @ IDR 300,000	7,000,000		7,000,000	
• Canoe/boat (4 × 1 m, engine 1.5 HP)	7,000,000		7,000,000	
• Storage and guard house, 4 × 4 m	5,000,000		5,000,000	
• Other supporting facilities	2,000,000		2,000,000	
Fixed costs	23,500,000	20.02	23,500,000	19.42
• Interest rate on investment	11,160,000		11,160,000	
• Depreciation	12,400,000		12,400,000	
Operational/variable costs:	93,900,000	79.98	97,500,000	80.58
• Seed-stock, 3,000 of 10 g @ IDR 12,500	37,500,000	31.94	37,500,000	30.99
• Feed:				
– Alternative I (using artificial feed) 2700 kg (3000 × 0.6 kg × SR – 50% × FCR – 3) × IDR 12,000/kg	32,400,000	27.60	–	
– Alternative II (using trash fish) 7200 kg (3000 × 0.6 kg × SR – 50% × FCR – 8) × IDR 5,000/kg	–		36,000,000	29.75
• Labour: 1 × 24 × IDR 500,000	12,000,000	10.22	12,000,000	9.92
• Other cost 24 × IDR 500,000	12,000,000	10.22	12,000,000	9.92
Total cost (fixed costs + variable costs)	117,400,000	100.00	121,000,000	100.00
Gross return 3,000 × (SR – 50% × 0.6 kg) × IDR 200,000	180,000,000		180,000,000	
Gross profit (gross return – operating cost)	86,100,000		82,500,000	
Net profit (gross return – total cost)	62,600,000		59,000,000	
Return:cost ratio	1.53		1.49	

<sup>a</sup> IDR = Indonesian rupiah.

Source: Survey 2005

Notes: 1. The interest rate was assumed to be 18% per annum. 2. The life-span of all fisheries equipment was assumed to be 5 years. 3. Average harvesting size of grouper is 0.6 kg. 4. Survival rate (SR) was assumed to be 50%. 5. Feed-conversion rate (FCR) was assumed to be 3 for artificial feed and 8 for trash-fish feed. 6. One production cycle was assumed to take 24 months.

Findings in Lampung were similar. The return:cost ratio from tiger grouper culture in floating cages in Pahawang and Tanjung Putus of the Lampung Bay, sub-district Punduh Pidada of South Lampung was in the range 1.35-1.65.

In Batam, the commercial grouper fish farmers used stocking densities of 15-20 pieces/m<sup>3</sup> (size 10 cm) bought from Gondol, Lampung and Situbondo of East Java. The resulting return:cost ratio from 2.21 to 2.59, as detailed in Tables 8 and 9.

The greatest potential improvements to the developing grouper industry in Indonesia may come in terms of reducing the practice of illegal fishing in the coral-reef fishing ground, creating supporting activities for the industry (feed, labour, aquaculture facilities and equipment and trade), creating employment opportunities and increasing income for fish farmers.

Through a strategic research priority led by the Agency for Assessment and Implementation Technology, the Department of Marine Affairs and Fisheries has launched a program for intensive culture of grouper. The program has covered 20 provinces throughout Indonesia. In 2003, the total floating cages operated by this program was 22,470 units producing 38,769 t of live grouper (DKP 2004 in Anon. 2004). Apart from this program, the private sector and local government have also worked to establish this promising business.

**Table 6.** Typical investment, costs and returns for aquaculture of *Kerapu Macan* (tiger grouper, *Epinephelus fuscoguttatus*) in South Sulawesi, Indonesia, 2005

	Artificial feed		Trash-fish feed	
	Value (IDR <sup>a</sup> )	(%)	Value (IDR)	(%)
Investment	31,000,000		31,000,000	
• 1 unit of cages (floating, wood) 16 × 10 m (10 cages of 2 × 2 m)	10,000,000		10,000,000	
• Nets, 20 units of 2 × 2 × 3 m @ IDR300,000	7,000,000		7,000,000	
• Canoe/boat (4 × 1 m, engine 1.5 HP)	7,000,000		7,000,000	
• Storage and guard house, 4 × 4 m	5,000,000		5,000,000	
• Other supporting facilities	2,000,000		2,000,000	
Fixed costs	11,780,000	13.94	11,780,000	13.78
Interest rate on investment	5,580,000		5,580,000	
Depreciation	6,200,000		6,200,000	
Operating/variable costs:	72,720,000	86.06	73,720,000	86.22
• Seed-stock, 3,000 of 10 g @ IDR8,000	24,000,000	28.40	24,000,000	28.40
• Feed:				
– Alternative I (using artificial feed)			–	
4320 kg (3000 × 0.6 kg × SR – 60% × FCR – 4) × IDR8,500/kg	36,720,000	43.46		
– Alternative II (using trash fish)				
7560 kg (3000 × 0.6 kg × SR – 60% × FCR – 7) × IDR5,000/kg	–		37,800,000	44.21
• Labour: 1 × 12 × IDR500,000	6,000,000	7.02	6,000,000	7.02
• Other costs 12 × IDR500,000	6,000,000	7.02	6,000,000	7.02
Total cost (fixed costs + variable costs)	84,500,000		85,500,000	
Gross return 3000 × (SR – 60% × 0.6 kg) × IDR80,000/kg	86,400,000		86,400,000	
Gross profit (gross return – operating costs)	13,680,000		12,680,000	
Net profit (gross return – total cost)	1,900,000		900,000	
Return:cost ratio	1.02		1.01	

<sup>a</sup> IDR = Indonesian rupiah.

Source: Survey 2005

Notes:

1. The interest rate was assumed to be 18% per annum. 2. The life-span of all fisheries equipment was assumed to be 5 years. 3. Average harvesting size of grouper is 0.6 kg. 4. Survival rate (SR) was assumed to be 50%. 5. Feed-conversion rate (FCR) was assumed to be 3 for artificial feed and 8 for trash-fish feed. 6. One production cycle was assumed to take 24 months.

**Table 7.** Financial analysis of aquaculture of tiger grouper in floating cages using commercial pellet feed or trash fish in Bali, Indonesia, 2005. Costs are in Indonesian rupiah.

Category	Type of feed	
	Commercial	Trash fish
1. Investment cost	9,000,000	9,000,000
– Floating cage of 2 × 2 m with 6 holes	6,000,000	6,000,000
– Other culture equipment/facilities	3,000,000	3,000,000
2. Fixed cost	600,000	600,000
– Depreciation		
3. Variable costs	8,920,000	8,000,000
– Fry 1,500 pieces (8 cm) × IDR4,000/piece	6,000,000	6,000,000
– Commercial feed 160 kg × IDR12,000	1,920,000,–	1,000,000
– Trash fish 500 kg × IDR2,000	1,000,000,–	1,000,000
– Labour cost 4 × IDR250,000		
Total cost	9,520,000	8,600,000
Gross revenue	14,006,250	11,812,500
1500 ekor × SR × IDR11.250/ekor (15 cm × IDR750,–/cm)		

**Table 7.** Financial analysis of aquaculture of tiger grouper in floating cages using commercial pellet feed or trash fish in Bali, Indonesia, 2005. Costs are in Indonesian rupiah.

Category	Type of feed	
	Commercial	Trash fish
Profit	4,486,250	3,212,500
Ratio of return over cost	1.47	1.37
Rentability (%)	47,12	37,35
Payback period	2,12	2,68
Break even point (IDR/piece)	7,620	7,190.

Source: Survey 2005.

**Table 8.** Financial analysis of monoculture of humpback grouper (*Cromileptes altivelis*) in floating net cages in Batam, Indonesia, 2005

Category	Value (IDR <sup>a</sup> )
Investment:	
• floating net cages	12,000,000
• fisheries equipment/facilities	7,500,000
Fixed costs:	
• depreciation of floating net cages	4,000,000
• depreciation of fisheries equipment/facilities	1,500,000
Variable costs:	
• humpback grouper seed 2.550 piece × IDR8,000	20,400,000
• feed 3000 kg × 10 month × IDR1,700	16,000,000
• labour 2 × 12 month × IDR300.000	7,200,000
Total cost:	49,100,000
Gross revenue 385.36 kg × IDR330.000/kg	127,169,000
Profit	78,069,000
Return:cost ratio	2,59

<sup>a</sup> IDR = Indonesian rupiah.

Source: Verified data of Manadiyanto et al. (2002)

**Table 9.** Financial analysis of combined aquaculture of humpback grouper (*Cromileptes altivelis*) and tiger grouper (*Epinephelus fuscoguttatus*) in floating net cages in Batam, Indonesia, 2005

Category	Value (Indonesian rupiah)
Investment:	
• floating net cages	12,000,000
• fisheries equipment/facilities	7,500,000
Fixed costs:	
• depreciation of floating net cages	4,000,000
• depreciation of fisheries equipment/facilities	
Variable costs:	1,500,000
• <i>Cromileptes altivelis</i> fry	10,200,000
• <i>Epinephelus fuscoguttatus</i> fry	4,800,000
• Feed	14,000,000
• Labour	7,200,000
Total cost:	41.700.000
Gross revenue	92,157,000
• <i>Cromileptes altivelis</i>	(70,317,000)
• <i>Epinephelus fuscoguttatus</i>	(21,840,00)
Profit	50,457,000
Return:cost ratio	2.21

Source: Verified data of Manadiyanto (2002).

A verification survey conducted during 2005 indicated that the number of cages for grouper culture has significantly increased in the Riau province, from fewer than 100 units in the late 1990s to more than 1,000 units in 2005. There were slight increases in Bali and Lampung provinces, but in South Sulawesi the number of fish farmers remained the same as 2-3 years before.

### **Description of the supply chain**

As previously reported (Koeshendrajana 2005), a typical supply chain for grouper fish is as follows. Production, either from capture or culture activities, is directly gathered by collectors or traders in the producing area, using carrier vessels. In practice, producers have been tied to collectors providing advance payment for their estimated production. In this case, producers have insufficient access to price information. Traders, on the other hand, hold all the current information regarding the supply and demand for that particular fish. This implies that producers are in a weak bargaining position.

Producers were identified as fishers and fish farmers. As indicated in Table 2, grouper were caught from many different provinces and fishing grounds. Due to the high price of live-grouper for export destinations, producers are attracted to produce more and more. For the fishers, their fishing activities have become intensive. Expansion of fishing intensity and fishing grounds have resulted in an increase in the operating costs of fishing. However, most key respondents pointed out that there was a tendency for decreasing grouper stock in many fishing grounds. This, in turn, leads fishers to seek and expand their fishing to deeper water or even areas farther away. This situation has implicitly shown that resource rent generated from the fishery has become lower than previously. This was also compounded by the fact that illegal fishing gears and devices, such as electricity, explosives and poisons, are widely used by some fishers. With the spread of live-grouper fishing, new fish collectors (*pengepul*) would likely also appear.

For fish farmers, to meet continuing demand for live grouper, grouper culture in floating cages has become a promising activity to get a higher profit. Initially, floating-cage culture for grouper may begin with the tradition of fish collectors of wild live grouper establishing in temporary locations where they often keep their small grouper bought from fishers for several months to meet marketable size. Even for fish of marketable size collected, these floating cages are often used as transit or stopover points for fish before they are exported to the country of destination, such as Hong Kong, Taiwan, Singapore and mainland China. As detailed in Table 1, average growth of culturing grouper in the floating cages during the past 5-10 years was significantly higher than the growth in capture fisheries. Reasons for this include the success in broodstock management and breeding programs, government advocacy to promote grouper culture and higher demand for the particular species. However, problems associated with the culture activity remain, especially in regard to feed used, diseases, deformities and high mortality of the fish stock. With best-culture practice, it can be said that, through aquaculture, demand for LRFF may possibly be met, and simultaneously, pressure on the environment due to illegal fishing of wild grouper may be substantially reduced.

The high price of fish in the importing country may also reflect the complex structure of the trade. As reported by Sadovy et al. (2003), grouper fish are produced locally over a widespread area of production, either from capture or culture activities. The fish may pass through several levels of trade and go to the country of destination by sea or air. Problems may arise due to poor infrastructure between the collection sites and ports or airports.

An intermediate supply chain is comprised of collectors and wholesalers. Fish collectors exist because of the wide spread of live grouper production centres. They contact each producer to

get information of the availability of live grouper of marketable size. Whenever a certain amount of live grouper is available, he sets the price and collects the live grouper from producers. In most cases, fish collectors sell their fish to the wholesaler or exporter, but occasionally to food services. In South Sulawesi, the grouper collection system follows the tradition of *Punggawa* and *Sawi*. *Punggawa* is the asset owner who usually provides the boat, fishing gear and meets other expenses either related to fishing activity or the household's daily expenses. *Sawi* is the person who goes fishing using the facilities provided by the *Punggawa*. The word *Punggawa* has two different meanings. *Punggawa Kapal* is the person who is responsible on the vessel. This *Punggawa* is sometimes called *Juragan*, *Kapten* or even *Nakhoda*. *Punggawa Pulau* is the asset owner. In the Spermonde Islands, the *Punggawa Pulau* acts as the *Punggawa Kapal*. The fish collector is locally called *Pa Balolang*. This is the person who collects and carries the fish to the target market. Transactions of fish caught by fishers and *Pa Balolang* usually occurs at a special location (island) that is not known to many people. *Pa Balolang* sell the caught fish from fishers to the landing site (*Tempat Pelelangan Ikan, TPI*) through *Papalele* or *Punggawa Pengumpul Darat*. In Bali, the fish collector also represents the fish exporter. The role of fish collector in the region is not clear.

Studies by Andamari et al. (2005) indicated that the main export destination for grouper from Bali was Taiwan (>90%), followed by Japan and Singapore. Interestingly, a verification survey conducted during August 2005 suggested that the grouper production was mainly from aquaculture, and mode of transportation was by carrying vessel directly to Hong Kong.

In Lampung, there are 2-3 grouper fish collectors. They directly contact the exporter whenever the minimum amount of fish to be sold is reached. Information from the Forum Communication of Grouper Enterprise in Lampung (*Forum Komunikasi Pengusaha Kerapu Lampung, FOKKEL*) indicated that only a small portion (3%) of the grouper is sold to food services. The rest is sold to the exporter. About 90% of it is exported by carrying vessel. The pattern in Riau province (Batam) is similar to that in Bali. Almost 70% of live grouper are exported by carrying vessel to Singapore and Hong Kong. A survey in 2005 indicated that 30% of grouper production was consumed locally through food services.

In the supply chain, consumers can be viewed in terms of either domestic or export markets. The domestic market for grouper is represented by traditional market and food services, such as hotels, restaurants and food stalls. Such was the case in the Nanggroe Aceh Darussalam (NAD) and other places in Sumatra. A year after the tsunami, traditional market and food services were serving relatively moderate amounts of fresh grouper daily, but no statistical data were recorded on this.

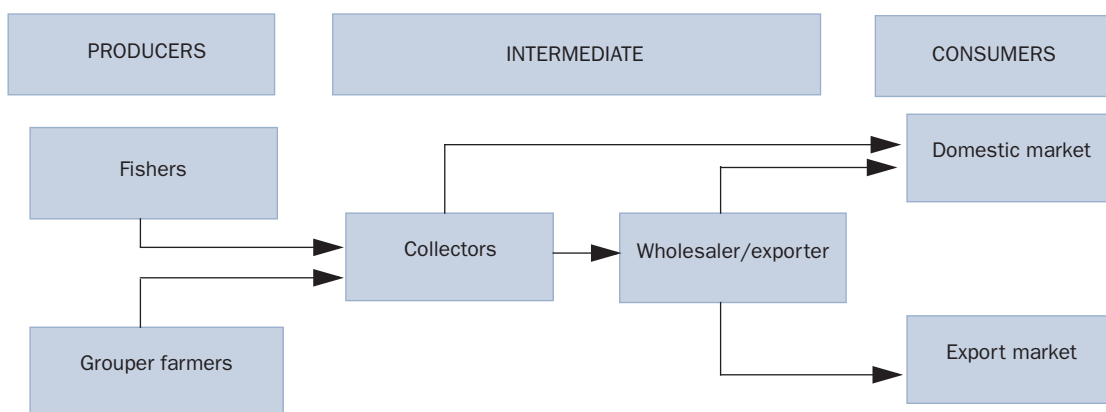
The export market component in the supply chain may comprise importers, wholesalers, retailers and food services in the importing country. Exporting is often good for fish business. As pointed out by Palfreman (1999), producers may receive higher earnings from exporting than they do from selling into the domestic market.

### **Supply chain for live grouper**

Different types of supply chains exist in the LRFF trade. From Figure 2, three types of supply chain can be identified:

- producers (fishers and/or fish farmers), intermediate (fish collector) and consumers (domestic demand and/or exporter/importer)
- producers (fishers and/or fish farmers), intermediate (fish collector 1, fish collector 2) and consumers (exporters/importers)
- producers (fishers and/or fish farmers) and consumers (exporters/importers).

From fish collector to producers, there are three types of marketable size: (1) baby, less than 0.5 kg per piece; (2) super, 0.5–1.3 kg per piece, and (3) greater than 1.3 kg per piece. The corresponding prices are: (1) IDR40,000–50,000; (2) IDR100,000–125,000, and; (3) IDR125,000–150,000. From fish collectors to exporters, there are four types of marketable size: (1) 0.3–0.5 kg per piece; (2) 0.5–1 kg per piece; (3) 1–1.3 kg per piece, and (4) greater than 1.5 kg per piece. The prices received by fish collectors and exporters for the various market sizes of grouper are given in Table 10.



**Figure 2.** Typical marketing channels of the live reef-fish (grouper) in Indonesia, 2005 (adapted from Koeshendrajana (2005)). The delivery from collectors to grouper farmers is fry or broodstock of LRFF (grouper) caught by fishers. The domestic market is predominantly for food services, such as hotels, fish food stalls and large restaurants. Collectors sometimes buy live grouper from other collectors to meet their quota.

Various expenses have to be paid by the exporter, including packing, transportation, cargo and administration. Two types of packaging stage are normally practised. The first type is at the production site (Lampung or South Sulawesi) and the second type at Jakarta Airport. The transport cost from Hassanudin Airport in South Sulawesi to the Cengkareng (Jakarta) Airport is IDR7,000/kg, whereas international transport from Jakarta to Hong Kong, cargo costs US\$1.20/kg. Administration for the international destination (Jakarta–Hong Kong) costs IDR300,000–IDR400,000.

**Table 10.** Prices received by fish collectors and exporters for different sizes (weight) of live grouper

Size (kg)	Price received by collector (Indonesian rupiah, IDR)	Price received by exporter (IDR)
0.3–0.5	100,000	166,700
0.5–1	230,000	285,790
1–1.5	230,000	381,050
> 1.5	240,000	452,500

Note: Calculated based on US\$1 = HK\$7.81 = IDR9,300.

### Issues and special interest

The grouper industry is a significant current and potential future business in the fisheries, but a great threat to grouper habitat. Damage to coral reefs must be addressed. Studies by Barber and Pratt (1997) pointed out that coral-reef destruction due to the use of cyanide in fishing may not end until government takes strong action to set in place effective policies to eradicate it and to encourage sustainable live-reef fisheries. The use of cyanide to catch fish is illegal in virtually every country of the Indo-Pacific, but it is easy to make big profits by such illegal fishing. Policy reform is likely to be another way for government to anticipate and

overcome other serious problems that might arise. Policy reform in this context means more than simply passing laws. It also involves establishment of effective institutions to monitor the live reef-fish trade, enforce the laws, and provide economic incentives for fishers, traders and consumers to shift to ecologically sustainable, cyanide-free reef fishing.

Long-term sustainable grouper fisheries management strategy should immediately be developed and implemented. This plan of action should include various aspects of biology, ecology, social, economic and institutional arrangements. At the same time, alternative livelihoods for local fishers should be promoted. Respondents complaints concerning live grouper trading were in terms of unfair trade, in the sense that market information was not clear in terms of the species demanded or the characteristics of the product and prices. To overcome this problem, the development of some type of business centre for the live grouper market might be good approach in Indonesia.

### **Implications for stakeholders**

The implications for stakeholders in relation to LRFFT were identified as follows. For exporters, a HACCP certificate should be compulsory to obtain a license for exporting live grouper. Exporters should deliver market information to producers and should create a mechanism to ensure a realistic profit to fish collectors. Importers in Singapore, Hong Kong, Taiwan and mainland China should be asked to restrict purchase of LRFF to certified live grouper at or above a minimum standard size. A HACCP certificate may be a suitable way to deal with this matter. This is because HACCP programs are stipulated by the importer, not the exporter.

Consumers have an important role to play in pressuring the government to take action on imports of cyanide-caught fish. However, consumer pressure against cyanide fishing is virtually non-existent among the Chinese consumers of live reef-fish. This may be in line with what has been identified by Barber and Pratt (1997). Consumers in Hong Kong and mainland China are in the position to drive demand for LRFF from exporting countries. Therefore, consumers of LRFF in Hong Kong, Singapore, mainland China and other countries should be educated through a public awareness campaign explaining the potential risk to health and the environment of cyanide fishing for grouper, and the minimum harvest size for the particular fish.

For government, an effective plan of action should be set in place. The essence of this policy is to eradicate illegal fishing methods and encourage sustainable live-reef fisheries. There should be an ongoing public campaign to raise and maintain awareness of the risk of cyanide fishing and other illegal fishing methods for grouper so as to sustain the coral reef resource for the future livelihood of small-scale fishers. Alternative livelihoods for local fishers should also be promoted, to reduce the pressure on the fishery resource.

## **Concluding remarks**

Indonesia contributes significantly to the total amount of live reef-fish imported into Hong Kong and mainland China. The LRFFT constitutes a promising business that can be enjoyed immediately and which provides the most valuable and readily available fish export commodity in Indonesia. However, practices in the LRFFT in Indonesia have not created an equitable distribution of benefits to the various players working in the industry. Sound government recommendations should be investigated through modelling and simulation of various possible alternatives to ensure sustainability of the business.

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## Disaggregated projections on fish supply, demand and trade for developing Asia<sup>1</sup>

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### Introduction

Quantitative modelling of supply, demand, and trade for fish becomes very useful for evaluating development strategies and options if done for disaggregated fish types, production categories, and regions. With detailed analysis, one can identify priorities in terms of technologies for dissemination, research problems to address, regions on which to focus investments, and fish groups that contribute most to food security of the poor. Recently, a quantitative tool called the AsiaFish model (Dey et al. 2005a) has been developed for this purpose. This model is currently being applied to nine major fish-producing countries in Asia, namely Bangladesh, China, India, Indonesia, Malaysia, Philippines, Sri Lanka, Thailand and Vietnam.

Generating an outlook for fish in these countries is useful for at least three reasons. First, these countries account for a significant proportion of global production and consumption, contributing over 51% of output while absorbing 40% of consumption (FAO 2003; Delgado et al. 2003). Second, the growth performance of the fisheries sectors in these countries has been impressive: between 1991 and 2001, production in these countries growing at an average annual rate of 7.8%, more than twice the growth rate of world fish production. Fish consumption in these countries has also been rising rapidly; for example, the growth rates of consumption in China for 1985–1997 is 11.8%—over triple the global average of 3.3%. Third, fish is an important source of animal protein for these countries, with the share of fish in total spending on animal protein exceeding 70% for countries such as Thailand, China and Bangladesh (Dey et al. 2005b).

As argued in Dey et al. (2005a), existing food-sector models are ill-suited for the task of making fish-sector projections for these countries. With few exceptions, these models typically gloss over the heterogeneity of fish types, the presence of alternative production sources (i.e. capture versus culture), and the diversity of consumption demand across income groups or regions. The AsiaFish model addresses all these difficulties, as well as assorted data problems such as jointness of production and the mismatch of fish-type definitions in country-level data on production and consumption. This paper presents in summary form the method of, and results from, applying the AsiaFish model to the selected countries.

### Modelling the fish sector in the selected countries

#### The AsiaFish model

The AsiaFish model is a multi-market equilibrium model for evaluating the effects of technology and policy changes on the prices, demand, supply and trade of various fish types. It is divided into producer, consumer and trade cores. The consumer and producer cores are

<sup>1</sup> An earlier version of the paper was presented at the 12th biennial meeting of the International Institute of Fisheries Economics and Trade (IIFET), 25–30 July 2004, Tokyo, Japan.

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essentially two sets of demand and supply equations. The producer core distinguishes between fresh and processed fish, with the assumption that a fixed ratio of fresh-fish output is allocated to processed fish. The supply of fresh fish is also distinguished by domestic production source.

The consumer core of the model describes the behaviour of households, which can be disaggregated by region and/or income class. The demand functions are derived from a three-stage budgeting framework. The first stage divides consumption expenditure into food and non-food spending. The second stage determines the representative household's demand for fish as a whole. The final stage captures the demands for different types of fish, using the quadratic form of the 'almost ideal demand system' (AIDS).

The trade core of the model is composed of a series of export supply and import demand equations.<sup>3</sup> In the tradition of applied general equilibrium (AGE) models, domestic and foreign goods are treated as differentiated products, which is the Armington assumption. One advantage of this formulation is that it allows a fish type to be exported and imported at the same time ('cross-hauling' in the trade data). The aggregation follows a functional form characterised by constant elasticity of transformation (in the case of exports) or constant elasticity of substitution (in the case of imports). Model closure is attained at simultaneous equilibrium among the three cores. The closure condition is, however, considerably complicated by the presence of mismatched fish-type definitions in the production and consumption data. To complete the matching, the model identifies demand or supply *composites*; that is, a demand (supply) composite is one that is matched to several fish types on the supply (demand) side. The model then disaggregates the demand (supply) composite based on a constant elasticity function (in imitation of the Armington technique).

### **Disaggregation approach and data of the country models**

On the demand side, most of the countries decided to disaggregate between rural and urban regions except India (no disaggregation) and Sri Lanka (disaggregated into rural, urban and estate regions.) The three-stage budgeting framework was generally followed by all the countries. As a whole, 27 'fish types' can be identified from the various models for the demand side. Table 1 shows the number of fish types incorporated in stage 3. The number of fish types ranges from five in China to 15 in Indonesia. Of these fish types, the most common are 'shrimp and prawns' and 'tilapia', which are explicitly modelled in eight and seven countries, respectively. The classification of disaggregation also incorporated by price (low and high value), size (small and large), source (capture and culture) and species groups (e.g. cephalopods, molluscs).

For the production side, the model distinguishes supply based on production source. The simplest is a distinction between capture and culture (as in India); source distinction can also be quite detailed, as in Indonesia (which has inland and marine capture, as well as inland, marine and brackish-water culture). Supply disaggregation by fish type usually follows the classification on the demand side. For five countries, the number of fish types in the supply side exceeds those on the demand side, mainly because the distinction by production source is also a distinction by supply fish type; the distinction, however, is not made on the demand side, hence the demand counterpart is a composite fish type. Among the countries, Thailand has the largest number of demand composites.

The country models require data on demand, supply, trade and prices for each fish type, as well as additional information for such variables as income, prices of non-fish food types, etc.

<sup>3</sup> The need for explicit export-demand and import-supply equations is eliminated by the assumption that each country is a small open economy.

In order to ensure a consistent dataset, it was necessary to organise the information for each fish type into a *balance sheet*. Each balance sheet assumes that the total supply of each fish type ( $S$ ) is equal to imports ( $M$ ) and the sum of outputs from capture fisheries ( $Q_{CF}$ ) and aquaculture ( $Q_A$ ). On the other side, total demand ( $D$ ) is the sum of exports ( $X$ ), intermediate demand ( $ID$ ), rural household demand ( $HD_R$ ) and urban household demand ( $HD_U$ ). Finally, it must be the case that  $S = D$  or  $M + Q_{CF} + Q_A = X + ID + HD_R + HD_U$ . Table 2 presents the aggregate balance sheets in summary form for each country.

**Table 1.** Demand fish types and composites of selected countries

Country	Number of fish types	Composites	Elements
Bangladesh	10	Indian major carp	Capture, culture
China	5	Other finfish Other fish Shrimp	Capture, culture Capture, culture Capture, culture
India	8	None	
Indonesia	15	None	
Malaysia	8	Crustaceans	High value (shrimp), low value
Philippines	9	Shells Other fish	Mussels and oysters, other shells Grouper, tuna, carp, catfish, other capture, other aquaculture
Sri Lanka	7	None	
Thailand	12	Shrimp Other high value Other low value	Capture, culture Freshwater, marine Freshwater, marine
Vietnam	9	None	

**Table 2.** Aggregate balance sheets for fish supply and demand for the selected countries

Country, year	Bangladesh 2002	China 2001	India 2000	Indonesia 2000	Malaysia 2000	Philippines 2000	Sri Lanka 2002	Thailand 2000	Vietnam 2000
Quantity ('000 t)									
Output	1,951.5	26,564.7	5,481.6	5,567.8	1,435.5	2,633.2	265.4	3,250.2	2,370.0
Imports	–	1,899.8	70.7	40.3	313.4	154.3	71.1	103.6	–
Exports	40.9	2,390.7	307.9	587.5	132.2	131.6	12.9	755.2	574.0
Consumption	1,727.6	15,103.9	5,244.4	4,400.5	665.1	1,355.5	253.0	2,437.4	1,619.0
Intermediate demand	183.0	10,969.9	–	620.0	951.5	1,300.4	70.6	161.2	177.0
Value (US\$ million)									
Output	2,142.4	29,442.6	3,931.9	2,860.9	2,631.3	2,116.6	362.1	4,214.3	3,143.2
Imports	–	1,285.5	40.1	34.7	292.3	44.7	64.0	220.0	–
Exports	191.7	3,932.2	1,057.1	1,420.5	344.3	311.5	78.0	2,210.0	1,738.5
Consumption	1,750.4	12,111.5	2,915.0	1,262.9	781.8	1,025.8	251.2	2,103.3	1,372.6
Intermediate demand	200.3	14,684.4	–	212.2	1,797.5	823.9	97.0	121.1	32.1

As in other food-sector modelling studies, considerable difficulties were confronted in constructing the balance sheets. One difficulty was that, in each country, there is no single source for all the data needed in the model. Second, some of the raw data had to be transformed in order to suit the requirements of the model. Third, in some countries there are credible studies that indicate inaccuracies in the raw data. For example, China's fish production figures may have been seriously overestimated; hence, some of the output data were adjusted downward.

### Parameters of the model

The parameterisation approach was to estimate the relevant elasticities and response parameters for the consumer and producer cores, and to borrow elasticities for the trade core. Once obtained, these were transformed to suit the specification of the equations in Dey et al.

(2005a). The intercept terms of all the relevant equations were then calibrated to ensure that the model replicates the baseline dataset.

The estimation of the demand side yielded satisfactory results from the viewpoint of generating plausible values for the elasticities. In fact, elasticity estimates for the Philippines and India were used directly in the model, while those from Bangladesh and Malaysia required only minor modifications. In the cases of Sri Lanka, Thailand and Vietnam, estimates using national data were used in place of elasticities based on regional data. Lastly, demand-side elasticities from Indonesia and China relied heavily on estimates derived from a literature search and expert opinion. The initial estimates for these countries were not used for the projection exercises because (a) values did not perform well in simulation, and/or (b) problems in generating a disaggregation in the dataset for estimation that is consistent with that specified in the model.

Estimation of supply-side elasticities met with limited success. Except for Bangladesh, India and, to a lesser degree, Malaysia and Thailand, most of the supply-side elasticities were not satisfactory or did not perform well under simulation. Part of the explanation here lies in the incomplete data from which elasticities can be derived. The unavailability of reliable elasticity estimates for the supply side was addressed as follows. First, the country modellers attempted to borrow elasticities from the literature or other participants in the project. Second, for specific fish types for which such elasticities are not available elsewhere, it was decided to consult a panel of experts on plausible values for the elasticities.

Table 3 shows the average values of the elasticities used in the country models. Price elasticities for the supply side tend to be low; i.e. fish production is not very responsive to price changes. Price elasticities for aquaculture tend to be higher than their counterparts for capture fisheries. On the demand side, own-price and expenditure elasticities are higher for rural areas, implying a greater response to price and income changes in rural than in urban households.

**Table 3.** Summary of demand and supply elasticities for fish used in the country models

	Bangladesh	China	India	Indonesia	Malaysia	Philippines	Sri Lanka	Thailand	Vietnam
Supply									
Aquaculture	0.64	0.67	1.33	0.28	0.90	0.65	0.27	1.24	0.37
Capture	0.47	na	0.34	0.20	0.22	0.30	0.48	0.48	0.28
Demand									
Own price									
Rural	(2.55)	(0.80)	(0.98)	(1.20)	(1.21)	(1.43)	(0.89)	(0.56)	(1.11)
Urban	(0.37)	(0.45)	(0.98)	(1.18)	(1.21)	(1.37)	(0.89)	(0.62)	(1.33)
Estate							(0.89)		
Expenditure									
Rural	1.82	1.23	1.62	0.94	1.03	1.04	0.99	1.07	0.65
Urban	0.82	1.05	1.62	0.89	1.07	1.03	0.99	0.98	0.65

Note: Numbers in parentheses are negative.

## Projections for supply, demand and trade

Detailed projections from 2005–2020 were made for each country. Information is available for trends in production of selected fish types by source, consumption of different fish types by region, trade by fish type, and prices of fish types in consumption and production. However, as the disaggregation of the fisheries sector varies from one country to the next, no attempt is made to present the results for the individual fish types in this paper. The focus instead is on the potential trends in selected aggregates for the fisheries sector.<sup>4</sup>

<sup>4</sup> Detailed country-level data and projections are available upon request from the authors.

## Overview

Projection results are highly dependent on the assumed changes in the exogenous variables. Table 4 summarises the ranges in which the projections fall for each variable category (i.e. fish types etc.) The country models in general used historical trends in projecting income, input prices, non-fish commodity prices and regional populations. Countries differ, however, on assumptions about future technological changes in the fisheries sector. At one extreme, the Philippines and Malaysia simulations assume no productivity changes during the projection period. As such, the projections for these countries should be interpreted as one in which technology in year 2020 is the same as it is at present. At the other extreme are India and Sri Lanka, for which it is assumed that technological progress will raise the productivity of aquaculture by 3–4% per year.

## Projections for output

Projections for annual output increase over the period 2005–20 range from 0.21% in the Philippines to 3.57% in Sri Lanka (Table 5). The fastest growth rates are observed for Sri Lanka, India and China, while the slowest are in the Philippines and Indonesia. The relatively higher percentage increase in values suggests that fish prices as a whole are expected to rise over the projection period. Of the participating countries, the largest price increases are likely to be for India at approximately 6.2% (the difference between value and quantity growth).

Moreover, aquaculture is expected to expand for all countries, but especially China, Malaysia and Thailand. Overall, aquaculture production rises faster than capture production. All countries are expected to experience an expansion in capture fisheries, except for Bangladesh and the Philippines. The relatively high rates of increase for aquaculture output imply an increase in its share in total output. These changes are more pronounced for China, Bangladesh and Thailand. In the cases of China and Bangladesh, aquaculture is expected to account for roughly three-quarters of their total fresh fish in 2020. For China and Thailand, the increase in the share of aquaculture is mostly due to the relatively rapid growth of this source over the projection period. In Bangladesh, however, this is partly due to the projected output contraction in capture fisheries.

## Projections for consumption

Projections for demand indicate rising aggregate consumption for all countries, but especially Malaysia (Table 6). The results are mixed at the regional level. Despite the decline in selected regions for the Philippines, China and Malaysia, total consumption is still expected to expand because of the relatively small initial share of the contracting region in total consumption. In the case of Malaysia, the positive aggregate response was also augmented by the relatively large expansion in rural consumption.

The expansion in aggregate consumption can be traced to a combination of population growth and higher per-capita consumption. In the cases of Indonesia, Bangladesh and the Philippines—see Rodriguez et al. (2005) and Dey et al. (2005b), the low average annual increase in aggregate consumption relative to population growth suggests that per-capita consumption in these countries is expected to decline over the projection period. That is, the increase in aggregate consumption for these countries is due solely to population growth. Unless these countries target higher productivity growth in fish supply, the traditional role of fish as a source of animal protein for poor households will be increasingly undermined.

**Table 4.** Assumed percentage changes in the exogenous variables for fish supply, demand and trade, selected Asian countries, 2005–2020

Variable	Bangladesh	China	India	Indonesia	Malaysia	Philippines	Sri Lanka	Thailand	Vietnam
Population	1.8	(2.3)–2.64	1.5	1.66–1.82	1.5–2	2.2–2.35	(1.4)–2.9	1.0–1.1	1
Food price	3.1	0.375	6.7–9.0	4	1.5	4.33–7.77	1.2–2.5	3.5	1
Non-food price	3.1	0.375	8	na	3.08	8.85–8.98	4.3–7.4	3.5	Na
Input price	5	0.375	4.2–8.8	4.95	1.0–3.08	2.68–7.60	2–3.1	2.0–3.0	1
Export price	3.1	1	4.2–10.3	0.77	0.8	3.58–5.76	7.5–8.5	3.5	0.1
Import price	na	2	0	0.5	0.5	3.86–6.64	(4.2)–4.2	3.5	1
Per-capita income	6.2	4.5–5.5	5	8.77–8.96	3.29	8.85–8.98	4.0–11.0	6	9
No. of firms	0	0	0	0	0	0	1	0	1
Technology—capture	0	0	1.9	1	0	0	2	0	1
Technology—culture	0–5	1–5	3.8	2.0–3.0	0	0	1.6–3.0	1.0–2.0	1
Marketing margins	0	(2)	0	0	0	0	0.8–2.3	0	0.5

Note: Numbers in parentheses are negative.

**Table 5.** Projected growth in the output of fresh fish, 2005–2020, by country

	Value (%)	Quantity (%)	Aquaculture (%)	Capture (%)
Bangladesh	2.06	1.34	2.77	(2.02)
China	6.22	3.04	4.69	–
India	9.33	3.14	3.99	1.99
Indonesia	2.19	0.88	1.80	0.83
Malaysia	5.74	1.49	4.45	1.12
Philippines	4.52	0.21	2.17	(0.17)
Sri Lanka	6.39	3.57	3.60	3.33
Thailand	6.43	1.75	4.01	0.46
Vietnam	2.68	2.01	2.01	2.01

Note: Numbers in parentheses are negative.

**Table 6.** Projected growth in fish consumption and consumption per capita, 2005–2020, by country

	Consumption			Consumption per capita	
	Total (%)	Rural (%)	Urban (%)	Rural (%)	Urban (%)
Bangladesh	0.22	0.06	0.82	(1.74)	(0.98)
China	2.53	(2.00)	3.62	0.30	0.98
India	2.47	na	na	0.97	0.97
Indonesia	1.05	0.12	1.92	(1.54)	0.10
Malaysia	9.95	12.55	(1.85)	11.05	(3.85)
Philippines	0.50	(1.56)	1.38	(3.91)	(0.87)
Sri Lanka	3.91	4.45	0.42	1.55	1.82
Thailand	1.83	2.07	1.37	0.97	0.27
Vietnam	1.73	1.91	1.33	0.91	0.33

Note: Numbers in parentheses are negative.

## Projections for trade

Meanwhile for trade, imports and exports of fish are projected to increase except for Malaysia and the Philippines (Table 7). The results also point to the rising importance of foreign markets for South Asia and China. With the exception of Malaysia, the value of net exports is expected to be higher in 2020. This is consistent with the earlier finding that the value of production would tend to rise faster than the value of consumption.

**Table 7.** Projected growth of fish exports and imports, 2005–2020, by country

	Quantities		Values	
	Exports (%)	Imports (%)	Exports (%)	Imports (%)
Bangladesh	8.68	na	12.10	na
China	2.92	1.82	6.69	4.10
India	3.69	0.94	14.18	0.96
Indonesia	0.64	1.44	1.74	1.99
Malaysia	(2.67)	15.72	(1.38)	15.48
Philippines	0.24	(3.85)	5.08	2.77
Sri Lanka	4.69	7.32	10.12	7.32
Thailand	1.91	3.40	6.36	6.99
Vietnam	2.23	na	2.38	na

Note: Numbers in parentheses are negative.

## Projections under different scenarios

For impact analysis, we simulate the outcomes of faster technical progress. In the selected countries this is a realistic scenario for aquaculture. Globally, aquaculture is recognised as the primary source of growth in the fish sector (Delgado et al. 2003). Moreover, the presence of modern technologies and farming inefficiencies implies a potential for raising output without meeting fundamental resource constraints, such as limited farm area. This is in contrast to the case of capture fisheries which, in the selected countries, are found to be fully or over-exploited (Silvestre et al. 2004). Scenario 1 refers to faster productivity growth in freshwater aquaculture, while scenario 2 refers to faster productivity growth in brackish-water or marine systems.<sup>5</sup> This distinction may be roughly associated with higher productivity of low-value aquaculture (scenario 1) versus higher productivity of high value aquaculture (scenario 2), as brackish-water and marine aquaculture tends to produce the relatively more expensive fish products. This distinction can then be linked to food security, as poor households tend to consume low-value fish in greater proportion.

Results are reported in terms of average deviation from the baseline projection. Higher productivity of freshwater aquaculture leads to faster overall growth of output (Table 8). Of course the output growth tends to be higher in aquaculture, as it is the directly affected sector. The results for exports are, however, mixed; only in Malaysia do we observe a significant export boost from more rapid technical progress in aquaculture. On the other hand, only in Malaysia is there a zero impact of productivity growth on consumption; in the other countries, consumption tends to rise. This probably implies a welfare gain especially for the poor.

The results for scenario 2 are broadly similar to those of scenario 1. Higher productivity of high-value fish also leads to faster growth of output, especially in aquaculture (Table 9). In contrast, the export effects tend to be positive and larger, as brackish-water and marine culture tends to be more export-oriented than freshwater aquaculture. Lastly, we expect growth of total consumption for all the countries, though somewhat milder than that

<sup>5</sup> In the case of Thailand, productivity growth also rises for capture fisheries.

observed in scenario 1, as brackish-water or marine-cultured fish tend to be less important in the consumption basket. The results of these two scenarios suggest that, if a nation is aiming at improved food security, it is better-off targeting productivity growth in low-value aquaculture. If this comes at the expense of investments in high-value aquaculture, however, it may have to forgo some of the export growth attributable to the latter.

**Table 8.** Scenario of higher productivity of freshwater aquaculture: deviations from baseline growth rate, 2005–2020, by country. Values are percentages.

	Percentage rise in productivity growth	Total output	Aquaculture output	Quantity of exports	Total consumption
Bangladesh	1.0	0.20	0.27	(0.05)	0.28
India	5.0	0.03	0.01	(0.30)	0.08
Indonesia	3.0–5.0	0.19	1.20	0.00	0.21
Malaysia	1.0	0.66	2.94	2.55	0.00
Philippines	5.0	0.68	2.47	0.18	0.88
Thailand	1.0	0.14	0.77	(0.48)	0.31
Vietnam	1.0	0.17	0.51	0.21	0.13

Note: Numbers in parentheses are negative.

**Table 9.** Scenario of higher productivity of high-value fish in aquaculture: deviations from baseline, 2005–2020, by country

		Total output	Aquaculture output	Quantity of exports	Total consumption
Bangladesh	1.0	0.39	0.50	1.30	0.06
India	1.0	0.07	0.01	(0.16)	0.08
Indonesia	1–3	0.10	0.66	0.13	0.10
Malaysia	1.0	0.07	0.04	0.07	(0.18)
Philippines	1.0	0.06	0.21	0.21	0.04
Thailand	0.01 to 2.0	0.02	0.15	(0.07)	0.05
Vietnam	1.0	0.00	0.06	0.00	0.00

Note: Numbers in parentheses are negative.

## Concluding remarks

The AsiaFish model is a quantitative tool for analysing the supply and demand outlook and impact of policies, at a disaggregated level, to provide detailed guidance on the design of development strategies for the fish sector. The model has been applied to nine major fish producers in Asia to generate projections to 2020. Our results indicate that, with rising population and income, fish demand will continue to grow. Supply will also rise, with the bulk of the increase coming from aquaculture.

Growth of supply will, however, be slower, implying the long-run increase of fish prices. Nevertheless, in most cases fish consumption per person will continue to be maintained or perhaps even increase. The exceptions are Indonesia, the Philippines and Bangladesh, where a long-term decline in per-capita consumption is projected, unless reversed by aggressive productivity improvements. In our alternative scenarios, faster productivity growth will indeed increase output and raise total consumption.

The disaggregated nature of our model allows more targeted types of analysis. We have, for example, differentiated productivity growth between low-value aquaculture and high-value aquaculture. With this tool, we confirm as well as quantify the expectation that consumption increase is higher for the former, though export increases are higher for the latter.

The results presented so far are depicted in general terms due to the need to make succinct, cross-country comparisons. With the AsiaFish country models, however, we can generate disaggregated projections by fish type, production source and region, for fish supply, demand

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and trade. Moreover, we can devise detailed shock scenarios. In future work we intend to customise the impact scenarios to evaluate a wide range of policy options towards increasing and sustaining benefits from fisheries and aquaculture to poor households.

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# Projections of supply and demand for the trade in live-reef fish for food

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## Introduction

The live reef-fish food trade (LRFFT) is a significant subsector of regional trade in fish products. The principal consumer market is in Hong Kong (China), which also serves as a transshipment point to mainland China. Major suppliers include South-East Asian countries and Australia, though over 20 countries are contributing to the supply of live reef-fish.<sup>2</sup> The LRFFT has commanded increasing attention from policy makers and stakeholders given its high dependence on Asia-Pacific reef fisheries, where poverty is widespread and ecosystems are under great stress.

There are a number of important economic, social, and environmental issues involving future development of the trade that would benefit from research. These include both supply and demand issues. On the supply side, sustainability of the industry is in doubt due to over-exploitation and use of destructive fishing practices. On the demand side, quantifying the market potential for the LRFFT would be very useful for planning and policy affecting investment and technology development.

The specific objectives of this study are:

- to quantify future changes in supply and demand for live reef-fish as food arising from new technology, management practices, and economic growth
- to examine supply and demand under different future scenarios, to help identify policy options to improve market performance.

To conduct the analysis, we apply the AsiaFish model, supply-demand model for the fish sector developed by the WorldFish Center and national research partners throughout Asia. In this exercise, the AsiaFish model needed to be modified in two ways. First, live reef-fish for food is typically not included in the fish categories of the AsiaFish model, hence the data had to be collected and the model structure modified to incorporate this fish type. The data for this study were collected from Hong Kong, as well as countries included in AsiaFish, namely China, Indonesia, Malaysia and the Philippines. Second, the AsiaFish model consists of independent, country-specific models: to represent *trade* in live reef-fish for food, the individual country models had to be combined through international trade in live reef-fish. Once modified, the AsiaFish model could then be applied to examine future supply and demand for LRFFT, under the most likely and alternative scenarios.

Two interesting questions on the future of the LRFFT are as follows:

- Despite rising demand in Hong Kong and China, will stagnant or deteriorating capture supplies restrict the growth of LRFFT?

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<sup>2</sup> Major types of reef-associated fish marketed as live are groupers (humpback, giant, leopard coral grouper, spotted coral grouper and others), wrasses and snappers. Live reef-fish for food are distinguished from live non-food fish (aquarium fish and fish fry), live fish not reef-associated (such as freshwater fish) and non-live fish (fresh or processed).

- What does it take to ensure the expansion of LRFFT? What is the significance of improved management of capture fisheries, or of technological progress in aquaculture?

The rest of this paper is divided as follows. The next section characterises the LRFFT. This is followed by a consideration of the extended AsiaFish model. The numerical implementation, scenarios, and results are then discussed. The paper ends with a summary and conclusions.

## The trade in live reef-fish for food

### Demand and supply conditions

Live reef-fish is regarded as a food delicacy in the Chinese community. Unfortunately, data specifically on domestic consumption throughout the region are difficult to obtain. The most likely sources of data—the nationwide household expenditure surveys—typically do not disaggregate fish to the level required to isolate even just reef-related fish, let alone live reef-fish. It is known, however, that the centre of demand is Hong Kong, which may account for up to 80% of regional trade (Graham 2001). It is likely that consumption in southern mainland China is also sizeable, with Hong Kong as the transshipment point. Chan (2000) estimates that up to 60% of Hong Kong imports are re-exported to the mainland.

Other countries in the region also consume live reef-fish, but in much smaller quantities. Domestic consumption of live reef-fish in the Philippines, for example, is estimated to be less than 5% of total production (Mamaug 2004). In countries with sizeable ethnic Chinese communities (e.g. Singapore and Malaysia) the share of domestic consumption is likely to be higher.

Supply of live reef-fish originates either from capture or culture. All the fish types marketed as live reef-fish may also be sold as fresh (dead) fish, although the production technique for delivery of live fish is different from that of fresh fish. Capture requires either hook and line, or poison (a method that is illegal in most countries). Meanwhile, aquaculture of live reef-fish usually requires cages, and rearing practices that are highly protective and selective of fish quality. Moreover, aquaculture remains dependent on grow-out of wild juveniles; only recently are hatchery technologies and brood-stocks being developed for full-cycle aquaculture of the most common reef fish. An estimated 40% of live reef-fish going into Hong Kong are from aquaculture (Muldoon et al. 2005). Of course, in either case, transportation of live reef-fish is a delicate operation; up to half of the fish shipped die along the way (Sadovy et al. 2003).

Coral-reef fisheries in South-East Asia and the Pacific are dominated by small-scale inshore fishers, a sector that is among the poorest in the coastal community. Rising demand, combined with improved participation up the value chain, may yield considerable benefits for the coastal poor, but this is all contingent on the sustainability of the fisheries. By 1997, however, the live reef-fish trade was estimated to have already extracted up to four times the sustainable yield of South-East Asia's fisheries (Warren-Rhodes et al. 2004). This reinforces anecdotal evidence coming from fishing communities that attribute localised fish depletion to the trade (Erdman and Pet-Soede 1996). Common fishing techniques, such as use of cyanide, targeting of aggregating spawners, and capture of juveniles and immature fish, further undermine reef habitats and fish population recovery.

Further evidence of unsustainability is a pattern that has been compared with slash-and-burn agriculture: in a newly opened fishery, yields initially increase, reach a peak, then fall steeply or disappear entirely, and fishing activity moves on to other areas. The recent rise of aquaculture of live reef-fish is one response to the limits on expanding capture fisheries. However, sustainability of even this alternative will still depend on discovering commercially viable technologies for hatching and rearing larval fish, as well as reducing dependence on wild-caught trash fish as food for aquacultured stock (Sadovy et al. 2003).

The overall impression of weakened ecosystems and unsustainable yield is reinforced by individual country studies. For Indonesia, Cesar (1996) estimates that poison fishing inflicts a loss of US\$46 million per annum due to reef destruction and over-extraction. In the Philippines, for a major fishing site (Coron), the exploitation rate for leopard coral grouper is estimated at 0.78; live coral cover in non-impacted sites was 50%, compared with only 5–40% in impacted sites. These indicate over-exploitation and coral bleaching (Mamaug 2004).

### International trade: the case of Hong Kong

For Hong Kong, data on the live marine-fish trade, in both value and volume terms, are collected by the Agriculture and Fisheries Conservation Department (AFCD). Note that due to the absence of import duties, reporting of imports is not compulsory. While this may undermine data quality, it may also improve accuracy, as tax evasion is not an issue. AFCD data (AFCD 2000–05) distinguish imports and exports by mode of transportation; data for fish transported using Hong Kong fishing vessels are rather sparse. In 2004, the share of imports through fishing vessels was only 19.6% of all imports by volume; this was down from a 34.6% share in 2000. Reports in the literature suggest that fishing vessel figures are underestimated by half (Sadovy et al. 2003), based on estimates from AFCD itself; however, the author could not corroborate this figure during a visit to AFCD. Moreover, even if true, the underestimate applies to only the fishing vessel component. Throughout this study we have opted to adhere to the AFCD data.

For fish transported by other means, a breakdown is available by fish type and country of source or destination (Table 1). Note that the figures here exclude Hong Kong vessels but include all kinds of marine fish. By volume, major exporters are Thailand, China, the Philippines, Indonesia, and Australia. The other countries, such as Taiwan (China), Japan, Maldives, Vietnam, Papua New Guinea, Marshall Islands and others, together accounted for less than 5% of total import value.

**Table 1.** Live marine-fish imports into Hong Kong in 2004, by country of origin and by all modes of transport except Hong Kong fishing vessels

	Volume (kg)	Value (HK\$'000)	Percentage of total value
Thailand	2,755,498	89,495	13.5
China	2,731,484	28,428	4.3
Philippines	1,557,735	140,231	21.1
Indonesia	1,040,575	114,800	17.3
Australia	981,516	167,369	25.2
Malaysia	965,442	71,611	10.8
Taiwan	314,729	24,218	3.6
Japan	129,316	9,538	1.4
Other countries	219,994	18,099	2.7
Total	10,696,289	663,789	100.0

Note: HK\$100.00 = US\$12.84 in 2004 ([www.oanda.com](http://www.oanda.com))

Source: Agriculture and Fisheries Conservation Department.

The volumes of imports from Thailand and China are by far the largest, but imports from Australia are largest in value terms (25%), suggesting specialisation by Australia on the high end of the market. Just behind Australia is the Philippines (21%), whose volume of exports is also large. Other major exporters by value are Indonesia, Thailand and Malaysia; China accounts for less than 5% of total import value into Hong Kong.

In terms of species, by far the biggest market share belongs to leopard coral grouper (Table 2). If we, somewhat arbitrarily, differentiate high-value from low-value reef-fish at about

HK\$100/kg, then high-value fish account for over 52% of import value. Note that even most of the 'low-value' fish (referring to those priced at HK\$50 and above) may be regarded as high value relative to other, more common, fishes in the market. Furthermore, the 'Other marine fish' category includes an unknown amount of non-reef-fish (which accounts for the large export volumes reported for Thailand and China in Table 1).

**Table 2.** Import share and price of live marine fish, 2004

	Percentage share in total import value	Price (HK\$/kg)
High-finned grouper	0.1	265
Humphead wrasse	0.2	152
Leopard coral grouper	50.7	143
Spotted coral grouper	1.0	113
Giant grouper	0.5	100
Flowery grouper	2.9	81
Tiger grouper	4.0	80
Other grouper	14.0	73
Green grouper	11.2	50
Mangrove snapper	0.1	23
Other marine fish	15.4	21

Note: Excludes fish transported using Hong Kong fishing vessels.

Source: Agriculture and Fisheries Conservation Department.

Finally, Hong Kong also exports live reef-fish for food, though this is almost entirely re-exports of imported fish. Official sources detect only a small amount of re-exports to China. Moreover, by 2004 the official re-exports to China had shrunk to miniscule levels (Table 3).

**Table 3.** Imports and re-exports of live marine fish in Hong Kong, 2000 and 2004

	2000	2004
Import value (HK\$)	649,085,000	663,789,000
Import volume (kg)	9,880,861	10,696,289
Export to China, value (HK\$)	29,154,000	713,000
Export to China, volume (kg)	231,149	17,965
Other exports, value (HK\$)	4,014,000	9,505,044
Volume (kg)	53,296	72,767

Source: Agriculture and Fisheries Conservation Department.

### International trade: the exporting countries

Data problems are encountered in the exporting countries included in the study. Live reef-fish for food became prominent in regional trade only in the 1990s, and statistical systems have yet to incorporate live reef-fish as a distinct category. In the production stage, data are available for most of the reef-associated fish in the major exporting countries, but none break down these figures into live or fresh form.

In the case of mainland China, isolating reef-associated fish in the data is difficult, as this category, covering only a tiny proportion of overall production, hardly figures in official statistics. Grouper aquaculture data began to be collected in 2003. Exports and imports to Hong Kong of 'live fish' are also recorded, but this includes all types of marine and freshwater fish (Table 4). Similarly, Hong Kong reports only imports of 'Other marine fish' from the mainland; in 2004 the unit value of these imports was only HK\$10/kg (AFCD 2005); these fish are therefore probably not the familiar reef-associated fish.

For Indonesia, export data are available for the category 'live marine fish' (Table 5). However, Hong Kong data report that Indonesia exports mostly groupers; in 2004, the 'Other marine fish' imports from Indonesia were only 1.4% of imports from that country (AFCD 2005). For

production, data are available for groupers, though no distinction is made as to marketing form (fresh or live). Production figures for grouper are much larger than export figures (all live marine fish), hence most output is not marketed live.

**Table 4.** Grouper aquaculture production and live-fish trade, mainland China, 2003–2004

	Quantity (t)	Value (US\$'000)
Grouper aquaculture:		
2004	33,003	33,003
2003	26,790	26,790
Imports of 'Other live fish' from Hong Kong		
2004	–	–
2003	41,081	5,636
Exports of 'Other live fish' to Hong Kong		
2004	–	–
2003	42,234	5,423

Source: China Society of Fisheries.

Note: Values converted using prevailing exchange rates ([www.oanda.com](http://www.oanda.com)).

**Table 5.** Grouper production and live fish exports, Indonesia, 2001–2004

	2001	2002	2003	2004
Export value of live fish (US\$)	8,131,085	5,213,531	3,532,234	–
– of which to Hong Kong	5,034,860	3,737,818	2,648,109	–
Export volume of live fish (t)	2,208.66	1,216.38	1,007.43	
Grouper production from capture				
Value (US\$)	61,797,559	61,746,114	81,854,686	–
Volume (t)	48,422	48,516	48,400	53,743
Grouper production from culture				
Value (US\$)	12,476,451	70,969,633	79,950,104	28,229,497
Volume (t)	3,818	7,057	8,637	6,552

Source: Department of Fisheries.

Note: Values converted using prevailing exchange rates ([www.oanda.com](http://www.oanda.com)).

For Malaysia detailed data are available for live reef-fish imports and exports (Table 6). The reason is that, due to marine protection of reef species, a permit system is imposed on foreign trade (in fact data are available by port of entry or exit). On the production side, data are available for cage culture of reef fish; again due to marine protection, most capture of reef fish is prohibited.

As with Indonesia, production value and volume are far in excess of recorded live-fish exports; the excess may be accounted for by non-live production or by domestic consumption of live reef-fish. The presence of sizeable domestic consumption cannot be eliminated, particularly as Malaysia imports live reef-fish (though in small quantities). Moreover, the data suggest that Hong Kong is not the only major destination. The other significant destination is Singapore. Exports to Thailand are negligible. (It might be conjectured that Singapore serves as a transshipment point for re-export to Hong Kong. However, Hong Kong data in 2004 show total imports from Singapore of only HK\$2,401,000, or a total of 30,823 kg.)

In the Philippines, the only recorded export of live fish is for grouper; practically all exports of grouper are in this form (Table 7). On the production side, no data are kept for live-fish production, though grouper production (capture and aquaculture) is recorded. Live grouper exports accounted for 96% of all live-fish exports in 2003; of the former, 98% went to Hong Kong. (Likewise, Hong Kong data report only insignificant quantities of non-grouper live-fish imports from the Philippines.) As with the other countries, export value and volume of live grouper is only a small component of overall grouper production, which is almost entirely from marine capture. Export data for the Philippines exhibit a decline over the past

few years. A similar trend is seen for Indonesia and Malaysia (Tables 5 and 6), but it is not clear whether this is due to contracting demand, supply, or both.

**Table 6.** Reef-fish aquaculture and live reef-fish trade, Malaysia, 2001–2003

	2001	2002	2003
Export value of live reef-fish (US\$)	1,924,870	2,463,936	3,590,294
– of which to Hong Kong	407,627	731,980	1,725,992
Export volume of live fish (t)	569.90	547.75	739.81
Import value of live reef-fish (US\$)	35,153	20,962	113,364
Grouper production from cage culture			
Value (US\$)	14,786,780	16,349,236	21,121,059
Volume (t)	3,597	3,897	4,684

Source: Department of Fisheries.

Note: Values converted using prevailing exchange rates ([www.oanda.com](http://www.oanda.com)).

One final issue to be flagged is the discrepancy between Hong Kong data and data from exporting countries. Typically, import values recorded in Hong Kong are larger than export values recorded in the originating country, based on comparisons of the most similar categories. This holds despite the fact that some imports are not included on the Hong Kong side (i.e. fishing vessels), while some exports may not be live reef-fish on the exporter's side. The reverse holds for volumes: import volumes recorded in Hong Kong are smaller than export volumes recorded in the originating country (Table 8).

There can be any number of reasons for the discrepancy, such as fish mortality, differences in categories, classification or reporting (either shipment value and volume, or destination), and so forth. Identifying the precise nature of the discrepancy and how to correct it is outside the scope of this study, though it must certainly be addressed by some means in the simulation model.

**Table 7.** Grouper production and exports, the Philippines, 2001–2003

	2001	2002	2003
Export value of live grouper (US\$)	11,315,567	10,679,762	9,105,414
– of which to Hong Kong			8,923,505
Export volume of live grouper (t)	4905	6608	6753
Export value of other live fish (US\$)	–	–	113,364
Grouper aquaculture			
Value (US\$)	569,618	651,799	935,749
Volume (t)	97	87.8	119.8
Grouper capture (t)	11,339	13,913	13,809

Source: Bureau of Agricultural Statistics.

Note: Values converted using prevailing exchange rates ([www.oanda.com](http://www.oanda.com)), except for official calculations in 2003.

**Table 8.** Comparison of national export data and Hong Kong import data, 2003

		China	Philippines	Indonesia	Malaysia
Hong Kong data (a)	Value (HK\$)	37,465,000	155,631,000	122,429,000	54,597,000
	Volume (kg)	2,605,129	1,584,508	999,657	644,085
National data (a)	Value (HK\$)	362,315,092	67,925,586	20,624,876	10,009,071
	Volume (kg)	41,081,275	6,753,000	758,670	1,059,281
Ratio (a)/(b)	Value		2.29	5.94	5.45
	Volume		0.23	1.32	0.61

Notes: Hong Kong data pertain to all imports except those transported by Hong Kong fishing vessels. National data for China and Indonesia pertain to all live-fish exports to Hong Kong; for the Philippines, to all live grouper exports; for Malaysia, to Hong Kong exports of live groupers and snappers

Sources: Agriculture and Fisheries Conservation Department (Hong Kong), Department of Fisheries (Indonesia and Malaysia), Bureau of Agricultural Statistics (Philippines).

## The extended AsiaFish model

### Background on the AsiaFish model

The AsiaFish model, discussed in detail by Dey et al. (2005), is a multi-commodity, partial equilibrium model of the fish sector. It is composed of a producer core, a consumer core and a trade core. The producer core is divided into two production categories, namely capture and culture. For some of the fish types, the two categories are assumed to produce approximately homogeneous products; for others the distinction carries over in the fish type. The supply equations take the linear multiple-product form as derived from the normalised quadratic profit function. Proportional supply shifts are incorporated by the formalism of the 'effective price' (Alston et al. 1995).

The consumer core of the model represents the household fish demand following a two-stage budgeting framework. The first stage determines expenditure on fish as determined by income, prices of food and non-food items, under a double-logarithmic specification. The second stage determines fish expenditure shares under a quadratic 'almost ideal demand system' (AIDS) specification. For the producer and consumer cores, the model structure is an application of the Martin and Alston (1994) procedure to the fish sector. Demand for non-food uses of fish is incorporated as a fixed ratio to food demand.

The trade core incorporates exports and imports by differentiated-product formalisation, following Armington (1969). Demand is disaggregated into demand for domestically produced fish and demand for imported fish; imports and domestic production are treated as differentiated products. The import-domestic composite is formed by a 'constant elasticity of substitution' (CES) function. Likewise, total domestic supply is disaggregated into supply for domestic markets and export supply; exports and domestic production are also treated as differentiated products. The export-domestic composite is formed by a 'constant elasticity of transformation' (CET) function. The original AsiaFish model imposes the small open economy assumption, such that import and export prices are constant.

At equilibrium, demand equals supply. This requires identical fish types on the demand and supply sides. As the model accommodates an initial specification with non-uniform fish types on consumption and production, a matching procedure needs to be introduced. The matching also follows an Armington specification; that is, in the case of a demand composite (distinct supply fish types aggregated into a single demand fish type), disaggregation into separate demand functions is inferred from a CES function.

Similarly, in the case of a supply composite (distinct demand fish types aggregated into a single supply fish type), disaggregation into separate supply functions is inferred from a CET function. The inferred demand (supply) functions can then be matched to their counterpart supply (demand) functions. Model solution entails finding the domestic prices in each matched supply-demand function that simultaneously clears all markets. The model is coded in GAMS and a solution is obtained using the MINOS5 solver.

### Extending the model by incorporating LRFFT

The AsiaFish is developed independently for nine major fish producers in Asia, namely Bangladesh, mainland China, India, Indonesia, Malaysia, the Philippines, Sri Lanka, Thailand and Vietnam. As mentioned earlier, extending the AsiaFish model entails two tasks. The first is incorporation of Hong Kong into the set of countries. As LRFFT is mostly regional and centred on Hong Kong, it is no longer plausible to maintain the assumption of fixed world prices, at least for live reef-fish for food. Hence, this task also requires converting the erstwhile exogenous foreign price of live reef-fish into an endogenous variable, by linking

together the import and export equations in the selected countries through the appropriate market clearing conditions.

Second is the incorporation of live reef-fish for food in the model structure of the individual exporting countries. To address this, the modelling work needs to closely inspect the dataset and pay careful attention to representing market realities, while maintaining numerical solvability.

### Hong Kong and the endogenous world price

For this task, several options needed to be explored over the following issues:

- defining Hong Kong, vis-à-vis mainland China, i.e. between treating the mainland as a separate exporter or treating Hong Kong – mainland China as a single import destination
- modelling demand from different countries of origin
- disaggregating live reef-fish for food into their various types.

For the first issue, the preferred option would be to treat mainland China as a distinct trading partner. The main drawback, however, is the unavailability of benchmark data on live reef-fish production and trade in the mainland, whether on the mainland side or even on the Hong Kong side. Another problem is that fish types in the mainland China model are highly aggregated: there are only eight fish types (carp, tilapia, shrimp capture, shrimp aquaculture, other finfish capture, other capture, other finfish aquaculture, other aquaculture), representing tens of million of tonnes of output and tens of billions of dollars in value in the benchmark dataset. The disproportionality between these categories and the live reef-fish food category is likely to cause computational problems.

Hence, the selected option is to treat Hong Kong and mainland China as a single importing economy. Most live reef-fish consumed in China is obtained from Hong Kong, and possibly a large share of Hong Kong fish end up in south China; moreover, consumption preferences may be very similar in the two countries. The aggregation of Hong Kong and the mainland into a single behavioural structure for imports appears to be a viable assumption. Nevertheless, definition of exogenous variables (such as per-capita incomes) would need to be consistent with the Hong Kong – China definition.

Regarding the second issue: let  $FXL$  index the set of live reef-fish food types; the corresponding import quantities and import prices in HK-China are, respectively  $QDHK_{FXL}$  and  $PHK_{FXL}$ ; prices are in Hong Kong dollars. These variables are composites, to be further distinguished by import source, i.e. we have  $QDHK_{FXL}^N$  and  $PHK_{FXL}^N$ , where  $N$  indexes the set of exporters to HK-China. Let  $\delta HK_N$  be a share parameter and  $\rho HK$  is a parameter of the elasticity of substitution between components of the live reef-fish composite. Using the Armington (1969) formulation, we posit the composite relations as follows:

$$QDHK_{FXL} = \left( \sum_N \delta HK_N (QDHK_{FXL}^N)^{-\rho HK} \right)^{-1/\rho HK} \quad (1)$$

The elasticity of substitution  $\sigma HK$  is obtained as follows:  $\sigma HK = 1/(1 + \rho HK)$ . For price we have:

$$PHK_{FXL} QDHK_{FXL} = \sum_N (PHK_{FXL}^N QDHK_{FXL}^N) \quad (2)$$

Using cost minimisation (or output maximisation) we obtain an expression for conditional demand of each country's export product:

$$QDHK_{FXL}^N = (\delta HK_N)^{\sigma_{HK}} \left( \frac{PHK_{FXL}^N}{PHK_{FXL}} \right)^{-\sigma_{HK}} QDHK_{FXL} \quad (3)$$

Let  $QDLRF_{FXL}^N$ ,  $PXLR_{FXL}^N$  represent the export quantities and prices from the exporting countries (the latter in domestic currency). Let  $\mu q_{FXL}^N$ ,  $\mu p_{FXL}^N$ , respectively, denote the adjustment factors for quantity and price, and  $ER_{FXL}^N$  the exchange rate between the Hong Kong dollar and domestic currency, such that the following holds:

$$\mu q_{FXL}^N = \left( \frac{QDHK_{FXL}}{QDLRF_{FXL}^N} \right), \mu p_{FXL}^N = \left( \frac{PHK_{FXL}^N}{ER_{FXL}^N PXLR_{FXL}^N} \right) \quad (4)$$

We can use the definitions in equation (4) to convert import demand in Hong Kong to the import demand facing the exporting country, on the assumption that the adjustment factors are fixed.

Using existing notation of the AsiaFish model, export supply  $QXLR_{FXL}^N$  is derived from total supply  $QSF$ , the price of the export-domestic composite  $PARX$ , the share parameter  $\sigma_2$ , and the constant elasticity of transformation  $\sigma_X$ , as follows:

$$QXLR_{FXL}^N = (\delta_2 x_{FXL}^N)^{\sigma_X} * \left( \frac{PXLR_{FXL}^N}{PARX_{FXL}^N} \right)^{\sigma_X} * QSF_{FXL}^N \quad (5)$$

The difference here is that, unlike in the original AsiaFish,  $PXLR_{FXL}$  is endogenous and is determined by:

$$QDLRF_{FXL}^N = QXLR_{FXL}^N \quad (6)$$

This still leaves price and quantity of the composite live reef product (respectively,  $PHK_{FXL}$ ,  $QDHK_{FXL}$ ) undetermined. We model this using the constant-elasticity formulation, using the income in the importing country  $YHK$ , a parameter  $\gamma_{LRF}$ , the own-price elasticity of import demand  $\epsilon_{LRF}$  and the income elasticity of demand  $\eta_{LRF}$  as follows:

$$QDHK_{FXL} = \gamma_{FXL} PHK_{FXL}^{\epsilon_{HK}} YHK^{\eta_{HK}} \quad (7)$$

For the third issue, we consider that data are available within Hong Kong by various fish types. Demand elasticities for the various types have been estimated by Petersen (2006), and are reproduced in Table 9. Note that the species are all groupers (unless stated otherwise): highfin, humphead wrasse (high value); leopard, spotted, tiger, giant, flowery (medium value); green and mangrove snapper (low value). Elasticity estimates for these aggregate categories (high-value, medium-value and low-value live reef-fish for food) are insignificant and positive, except for medium value with a computed own-price elasticity of -0.88.

Income elasticities for the individual and aggregate fish types from Petersen (2006) are shown in Table 10. Few of the parameter estimates (corresponding to the elasticities) are significant. Only leopard coral grouper and flowery grouper have significant own-price coefficients. Meanwhile, nearly all the income-elasticity estimates correspond to statistically significant parameters.

The problem with disaggregating by fish type is therefore not on the demand side, but entirely on the supply side. There are no counterpart elasticity estimates for supply in each of the exporting countries; except for Malaysia, production data are not even disaggregated by

species. To force disaggregation, therefore, one must impute data values (perhaps using Hong Kong data), as well as own- and cross-price supply elasticities for these individual live-reef-fish types. This is, at best, a suspect undertaking; furthermore, computational problems are again likely, given that one relatively small fish sector in each of the exporting countries is being given detailed modelling treatment.

Hence, while the model code is flexible enough to incorporate more than one live reef-fish type, a decision was made to use only one live reef-fish type, called *LRF*. This raises the additional problem of aggregating the demand estimates obtained in Petersen (2006). Resolution of this is discussed under 'Numerical implementation and results'.

**Table 9.** Price elasticities by species

WRT:	Hfin	Hump	Leop	Giant	Tiger	Spot	Flow	Green	Man
Hfin	<b>-1.55</b> (1.08)	-2.40 (0.96)	-0.04 (0.27)	-6.82 (1.66)	0.33 (0.20)	0.24 (0.34)	1.48* (1.97)	-0.15 (0.35)	1.13 (0.71)
Hump	1.20 (0.82)	<b>2.79</b> (1.07)	-0.10 (0.61)	-1.06 (0.37)	-0.85 (0.50)	-1.41* (1.95)	0.55 (0.70)	0.22 (0.49)	-0.09 (0.05)
Leop	-1.18 (1.14)	0.58 (0.32)	<b>-0.80**</b> (6.96)	2.42 (1.26)	-0.82 (0.70)	-0.90* (1.79)	-0.95* (1.76)	-0.40 (1.32)	-0.81 (0.71)
Giant	-0.75 (1.14)	0.06 (0.04)	0.10 (1.10)	<b>-1.29</b> (0.75)	0.36 (0.38)	-0.90** (2.25)	-0.13 (0.30)	-0.35 (1.46)	0.18 (0.20)
Tiger	0.77 (0.49)	-1.36 (0.52)	-0.10 (0.59)	1.46 (0.45)	<b>1.01</b> (0.59)	0.94 (1.29)	-0.59 (0.75)	0.09 (0.20)	1.24 (0.74)
Spot	-1.28 (1.59)	0.46 (0.32)	-0.14 (1.57)	1.03 (0.63)	0.90 (0.97)	<b>-0.11</b> (0.27)	0.80* (1.87)	0.13 (0.53)	0.12 (0.14)
Flow	0.54 (0.41)	0.94 (0.40)	0.30** (2.01)	-1.98 (0.77)	-2.00 (1.32)	-0.24 (0.37)	<b>-2.36**</b> (3.38)	-0.31 (0.79)	-1.55 (1.05)
Green	-1.01 (0.66)	-2.94 (1.24)	-0.66** (4.34)	2.05 (0.77)	2.56* (1.65)	0.94 (1.43)	3.16** (4.43)	<b>0.48</b> (1.22)	2.12 (1.41)
Man	-0.84 (0.87)	-0.47 (0.28)	0.25** (2.33)	-1.07 (0.49)	-0.91 (0.82)	-0.44 (0.94)	-1.94** (3.80)	-0.47 (1.64)	<b>0.41</b> (0.38)

Source: Petersen (2006).

Note: Hfin = highfin grouper; Hump = humphead wrasse; Leop = leopard grouper; giant = giant grouper; tiger = tiger grouper; spot = spotted grouper; flow = flowery grouper; green = green grouper; man = mangrove snapper.

### Incorporating live reef-fish for food in the exporting countries

There are three exporting countries included in the extended AsiaFish, namely Indonesia, Malaysia and the Philippines. Together, these countries accounted for nearly half of market share of the Hong Kong LRFF in 2004. The rest of the exporters are aggregated into 'Other countries', with the assumption that these countries are price-takers in the regional market.<sup>3</sup> Data for the extended AsiaFish model are shown in Annex Table A1; note that this corresponds to the year 2000, the base year of the AsiaFish model.

The fish types in the Indonesia model are shrimp, tuna, mackerel (mack), assorted pelagic fish (APF), grouper, snapper, other finfish, carp, tilapia and catfish (Cfish). The demand and supply fish types are identical. The production categories are marine capture, inland capture, inland aquaculture, brackish-water aquaculture, and marine aquaculture. Grouper is produced by both marine capture and aquaculture. However, grouper exports in the Indonesia dataset are far in excess of the reported live reef-fish exports, given the inclusion of fresh-fish exports. Hence, a new fish category, live reef-fish (LRF) would have to be included.

<sup>3</sup> This is probably inappropriate for large players such as Australia and Thailand, but is unavoidable given the absence of Australia in the AsiaFish model, as well as the data gap for Thailand.

LRF is produced by both marine capture and aquaculture on an equal-share basis. Domestic consumption of LRF is set at very low levels. Elasticities for LRF are incorporated in the existing table of supply elasticities, using imputed values, usually imitative of elasticities for grouper (Annex Table A2).

**Table 10.** Income elasticities by fish type

Fish type	Elasticity	Significant?
Highfin grouper	2.15	Yes
Humphead wrasse	0.74	Yes
Leopard grouper	0.99	Yes
Giant grouper	-1.65	Yes
Tiger grouper	0.40	Yes
Spotted grouper	0.77	
Flowery grouper	0.81	
Green grouper	1.34	
Mangrove snapper	0.53	
High value	1.46	Yes
Medium value	0.95	Yes
Low value	1.17	Yes

Source: Petersen (2006)

The fish types in the Malaysia model are: anchovy, low-value fish (LVfish), high-value fish (HVfish), low-value crustacean (LVcrust), high-value crustacean (HVcrust), mollusc, tilapia and others. These are produced in three categories: marine capture, brackish-water aquaculture and freshwater aquaculture. The fish types on the demand side are the same, except 'crustacean' is a composite of HVcrust and LVcrust. On the whole, there is no obvious correspondence for live reef-fish for food. As with the Indonesia model, a new fish type, LRF, is added. Unlike in Indonesia, we imputed a domestic consumption equivalent to 10% of exports of LRF (Annex Table A1). This is in recognition of the sizeable Chinese community in the country (accounting for 23.7% of the population). LRF is produced only by brackish-water aquaculture. Elasticities for demand and supply with LRF are shown in Annex Table A2; the imputed values are imitative of those for high-value fish.

Finally, for the Philippines the fish types are: grouper, tuna, anchovy, roundscad (Rscad), other capture (OtherC), squid, shrimp, other shells (OShells), mussels and oysters (MOyster), carp, catfish (Cfish), milkfish (Mfish), tilapia, other aquaculture (OtherA), and processed fish (Process). The demand fish types are the same, except OShells is a composite of MOyster and OShells, and Other is a composite of grouper, tuna, OtherC, OtherA, carp and Cfish.

Unlike the other country models, exports of the category 'grouper' correspond almost exactly to live reef-fish food exports. Hence, to keep the original model mostly intact, no additional fish type was added. Instead, the elasticity of transformation of grouper into exports and domestic consumption was altered to reflect the distinctiveness of live fish consumed abroad, and fresh fish consumed domestically; the default value was reduced from 1.50 to 1.1. The other elasticities were kept intact.

## Numerical implementation and results

The extended AsiaFish model was first coded and solved to replicate the base dataset. This requires values for  $\epsilon_{HK}$ ,  $\eta_{HK}$  and  $\sigma_{HK}$ . For the first two, we attempted values based on Petersen's estimates (2006), i.e. inelastic own-price elasticities and unitary income elasticities. For the elasticity of substitution across exporting countries, we imposed a simple unity assumption; this reduces to the Cobb-Douglas specification with fixed market shares across countries.

Earlier, we asked some fundamental research questions. These questions can be explored with the aid of the following scenarios:

- *Baseline* or most likely scenario—income growth of 4.0% per year in Hong Kong – China; reduction in effective price of marine capture of LRF by 1% per year (i.e. productivity decline).
- *Management* scenario—same as baseline, except that effective price of marine capture of LRF grows by 1% per year (productivity improvement).
- *Technology* scenario—same as baseline, except effective price of marine aquaculture of LRF also increases by 1% per year (productivity improvement).
- *Optimistic* scenario—combination of management and technology scenarios.

Note that the baseline scenario for exogenous variables is sparse—resource productivity, technology, incomes and populations, are all held constant in the baseline. The fixed productivity assumption simply carries over the existing scenarios of AsiaFish. Constant incomes and populations are consistent with the relative unimportance of domestic consumption of live reef-fish; moreover, computational problems were encountered upon incorporation of a fuller set of exogenous variable projections. The economic growth scenario for Hong Kong – China is obtained from ADB (2005), with an assumed market share of 30% for China re-exports.

The other scenarios were posited to examine policy issues of interest. The management scenario assumes that an effective management regime is in place in capture fisheries for live reef-fish in the exporting countries. The technology scenario posits technical progress, due to R&D and dissemination of marine aquaculture technologies for live reef-fish. The optimistic scenario combines technical progress with effective management to identify the idealised market potential for the live reef-fish food sector.

Initially, the projection period was 20 years. The abovementioned growth rates are applied on a per annum basis, with the model iteratively solved so as to approximate continuous compounding of the exogenous variables. However, computational problems were encountered. We suspect that the imbalance of model structure is partly responsible, i.e. the modelling of international trade with endogenous world price is made in only a small subset of the model. That is, model solvability would have been greatly enhanced if all the world prices were determined endogenously. An alternative approach would have been, instead of extending the AsiaFish model, to apply the AsiaFish model structure to only the live reef-fish food trade, disaggregated by species. These approaches, however, require intensive data gathering, and lie outside the scope of this study.

Within the limits of the study, these problems were dealt with as follows:

- The projection period was shortened to 10 years. Indeed, a shorter projection period may be preferable to keep the simulations from straying far from the initial equilibrium at which the model parameters were calibrated.
- The values of  $\epsilon_{HK}$ ,  $\eta_{HK}$  were modified to -1.5 and 0.2, respectively. The own-price elasticity is now closer to intuition, although the divergence from the empirical study of Petersen (2006) should be noted. The low income elasticity is neither intuitive nor empirically based, but is forced for the sake of model solution.

As seen in the foregoing, numerous assumptions were made with respect to the model elasticities. Sensitivity analysis is applied by examining the results of the baseline simulation under different elasticity values. Given the enormous range of elasticity variants possible, we

opt to limit the sensitivity analysis to varying only  $\epsilon_{HK}$  and  $\sigma_{HK}$  to  $-2.0$  (more own-price elastic) and  $1.5$  (more degree of substitution between exports of different countries), respectively.

The results are presented in terms of percentage changes (for the baseline) or percentage point deviations from the baseline change. The total adjustment over the projection period is shown in Figures 1-10.

Baseline projections for live reef-fish food are shown in Figures 1 and 2. Prices do indeed rise as demand outpaces supply. In HK-China the increase is fairly modest, although in the exporting countries the increases are more substantial and, in the Philippines, the increase is quite sharp. The reliance of Philippine exports on declining marine-capture supplies accounts for this response. Rising demand still causes an expansion in LRFFT, as seen in the output projections; the Philippines, however, suffers a steep drop. Rather, import sources are diversified as Indonesia and Malaysia expand their output. However, given that the expansion is not commensurate with the increase in HK-China demand, imports from other countries must be taking up the slack.

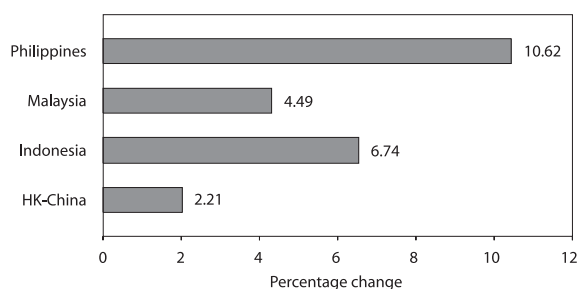
Under the management scenario (Figures 3 and 4), realistic improvements in productivity of capture supplies are sufficient to reverse the trends observed in the baseline. The import price in HK-China grows by a much slower rate than the baseline; in the case of the Philippines, the export price in fact drops. Interestingly, the model projects that export prices in Malaysia and Indonesia will grow slightly faster than under the baseline; this may be due to a relative decline in the composite price for live reef-fish, leading to a relative increase in quantity demanded across the board. In all countries, growth of the trade is greater than under the baseline; indeed, overall growth is faster by more than half of the baseline increase. In the Philippines exports surge, in excess of naïve expectations (i.e. an increase commensurate to the productivity improvement of 15%).

For the technology scenario (Figures 5 and 6), demand increases in HK-China are successfully met by even conservative improvements in the productivity of aquaculture. The change in import price in HK-China declines slightly relative to the baseline. Malaysia, which is wholly dependent on aquaculture supply, suffers a price fall; Indonesia meanwhile experiences a slower but still positive price growth (given its lower dependence on aquaculture). Export price in the Philippines, however, grows slightly faster than in the baseline. Compared to the management scenario, improved technology leads to a lower expansion of trade and a slower decline in price, suggesting that improvements in technology would have to be fairly rapid to be able to offset resource decline in capture.

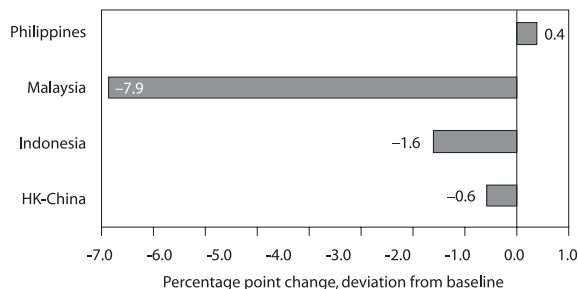
The optimistic scenario (Figures 7 and 8) suggests that better management and technology would lead to an 8.6% expansion of HK-China exports; the combination of the two is able to cause supply keep pace with demand—leading to a stable import price. Despite the combination, it is still the Philippines that experiences a rapid export expansion, combined with a steep decline in price. Malaysia undergoes a similar change, though to a lower extent; finally, Indonesia's outcomes hardly differ at all from the baseline scenario, as the brunt of the adjustment seems to have been borne by the Philippines, Malaysia and other countries.

Results of the sensitivity analysis (Figures 9 and 10) show that the projections are rather susceptible to the type of elasticity values imputed for HK-China. A higher own-price elasticity, as expected, causes a stronger price decline and a weaker output increase.

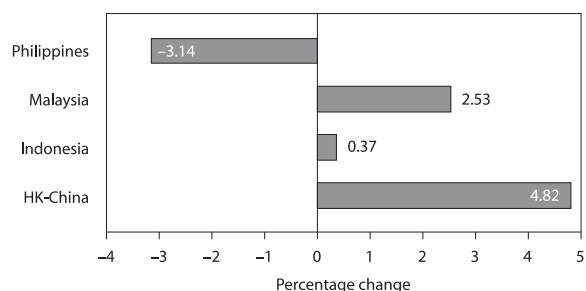
Moreover, the difference in the change is greatest for the Philippines, followed by Malaysia. In Indonesia, the difference in price change is hardly perceptible.



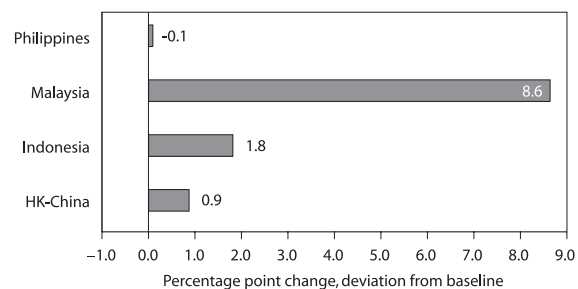
**Figure 1.** Growth of export price, baseline scenario



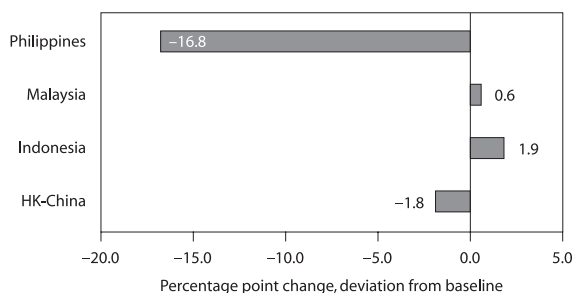
**Figure 5.** Growth in export price, technology scenario



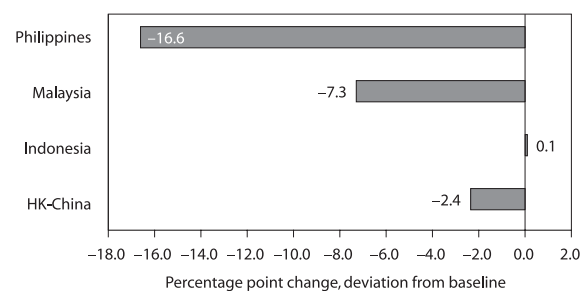
**Figure 2.** Growth of import and export volume, baseline scenario



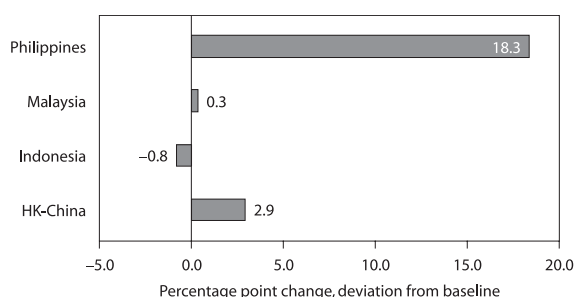
**Figure 6.** Growth in export volume, technology scenario



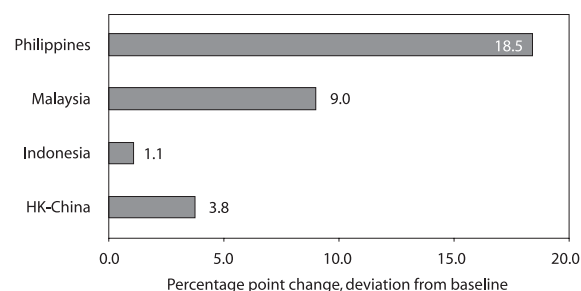
**Figure 3.** Growth in export price, management scenario



**Figure 7.** Growth in export price, optimistic scenario

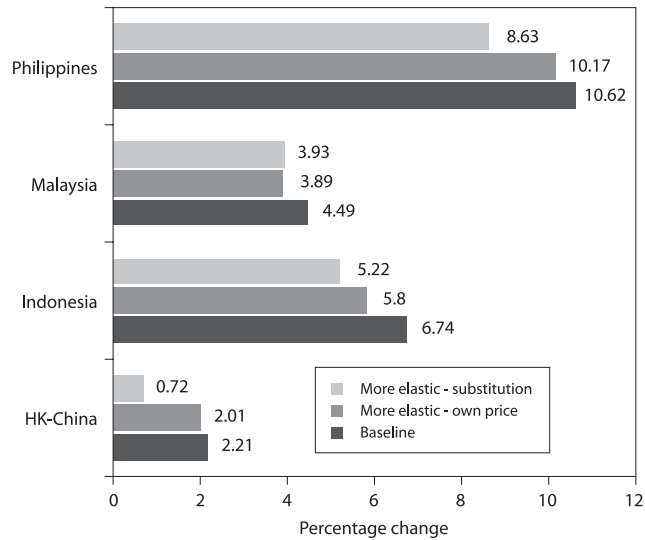


**Figure 4.** Growth in export volume, management scenario

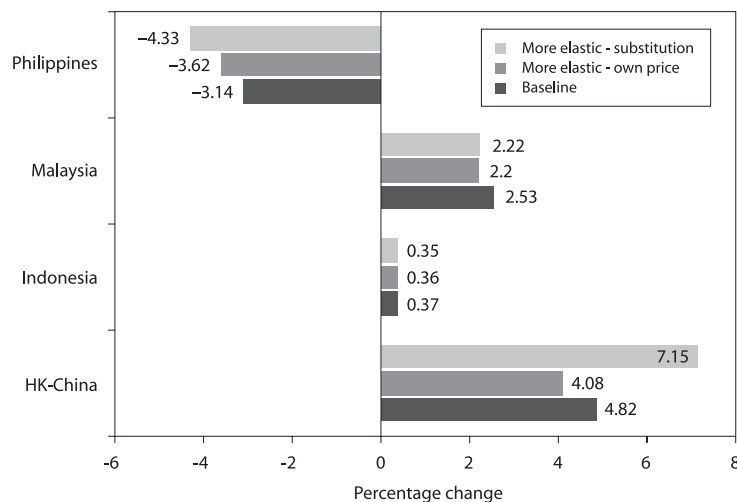


**Figure 8.** Growth in export volume, optimistic scenario

Somewhat unsettling is the effect of increasing the degree of substitutability. The change causes a difference in the change in price and quantity, the difference being even bigger than the effect of varying the own-price elasticity; that is, the elasticity of substitution is far from a trivial parameter. Its value requires careful estimation method, particularly as it can assume any value from 0 (perfect complements) to 1 (constant shares) to infinity (perfect substitution).



**Figure 9.** Growth of export prices for baseline scenario, under alternative elasticities



**Figure 10.** Growth of export volume for baseline scenario, under alternative elasticities

This sensitivity to parameter value is unsurprising, as HK-China is the major centre of trade. While this may highlight some concerns about robustness, it does indicate the importance of getting appropriate elasticities for the behaviour of import demand in HK-China.

## Summary and conclusions

This study intends to provide an outlook for supply and demand for trade in live reef-fish for food. The trade has risen rapidly in recent years, due to increasing demand in the main market, which is Hong Kong and southern China. However, concerns about the sustainability of the trade have been raised due to deteriorating fish stocks and reef status of in major trading partners in South-East Asia. Possible policy responses include improved management of reef-associated fisheries, as well as increased investment in the aquaculture technologies.

To investigate these issues we used an extended version of the AsiaFish model, which is a disaggregated model of fish supply and demand for Asian countries. The extension required

accumulation of a benchmark dataset for live reef-fish, and imputation of price and income response parameters (i.e. elasticities). However, a common data problem across the countries is the absence of data on the trade in live reef-fish for food, whether on the demand side, or even on the supply side. In China, collection of data on reef-associated species is problematic due to their relatively small proportion in the entire fisheries sector; for example, collection of data on grouper culture began only recently. Where data on reef-associated fish production are available, information about the product form (live or fresh) is not available. Finally, where export data on live fish is available, categories are often aggregated (i.e. all grouper, rather than the various grouper species).

Fortunately, data are available on Hong Kong imports, disaggregated by species and country of origin (except for a large and ambiguous category of 'other marine fish'). However, even here there is a striking discrepancy in terms of value and volume information on trade flows and values reported by Hong Kong and the exporting countries. Furthermore, official information on the re-export of fish to China conflicts with anecdotal evidence, adding further uncertainty into the brew.

Based on the data and some pragmatic assumptions, a benchmark dataset was compiled for the extended AsiaFish model. This entailed addition of a new fish type, except for the Philippines where exports of grouper could be closely approximated to the entire set of live reef-fish food exports. For the other countries (Indonesia and Malaysia) in the extended AsiaFish model, elasticities for supply were imputed, based on elasticities of similar fish categories; in the case of the Philippines, the elasticity of transformation into exports was modified. On the demand side, elasticities adopted from Petersen (2006) were initially applied. Hong Kong and China demand are lumped together into HK-China.

The simulations consist of 10-year projections using forecasts for economic growth in HK-China. We were forced to modify the elasticities in Petersen (2006) to obtain a model solution. In the baseline, most-likely scenario, we assumed a moderate decline in capture supplies. In the base case, growth in the trade is indeed restricted as demand growth outstrips supply, resulting in a rather sharp increase in prices. Exports based on capture fisheries are adversely affected. However, if the decline can be arrested and productivity of reef-associated fisheries improved through effective management, then these trends can be reversed. Improved technology would have similar effects for LRFFT prices, but less so as it is partially offset by continued deteriorating of capture supplies. Finally, in the best-case scenario (improved fisheries management and aquaculture technology), supply exceeds demand and prices decline, although all exporters experience vibrant growth. These findings underscore the importance of policy response to reverse the projected trends in LRFFT through timely interventions in both the capture and aquaculture sectors.

This study raises several issues for future research towards further modelling of the live reef-fish food sector. First is the availability of disaggregated, high-quality data from both importing and exporting countries. Second is the sensitivity of our results to price, income and substitution parameters, requiring a more rigorous empirical derivation of these parameters at the same level of commodity aggregation used in the model.

Both of the foregoing issues are related to the third, which is the need to further disaggregate the supply side of the model, both in terms of compiling benchmark data and to identify appropriate supply price response. Fourth, a richer set of projections would be available if more countries (particularly Australia and Thailand) could be incorporated into the extended AsiaFish model. This task would entail collection of data and estimation or imputation of a new set of supply elasticities.

Fifth, part of the reason behind numerical solution of the extended AsiaFish model is a structural imbalance, so to speak, in model development, where a traded sector with endogenous world price appears as a minor commodity within a larger model with exogenous world prices. We expect that a more comprehensive modelling of trade linkages in the AsiaFish countries for all the various fish species—combined with a broader and more disaggregated treatment of Hong Kong demand for fish (in addition to live reef-fish)—would improve rather than complicate numerical tractability. This is probably a case where more is really more.

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## Annex 1

### Data and elasticities for the extended AsiaFish model

**Table A1.** Baseline data for live reef-fish as food

		HK-China	Indonesia	Malaysia	Philippines
Import	Value (HK\$)	991,895,519	2,872	0	0
	Volume (kg)	15,099,288	100	0	0
Export	Value (HK\$)	0	63,425,000	16,694,337	96,468,966
	Volume (kg)	0	2,208,655	2,208,655	6,642,700
Domestic output—capture	Value (HK\$)	0	33,381,579		96,468,966
	Volume (kg)	0	1,162,450		6,642,700
Domestic output—culture	Value (HK\$)	0	33,381,579	18,549,264	0
	Volume (kg)	0	1,162,450	2,454,061	
Domestic consumption	Value (HK\$)	991,895,519			
	Volume (kg)	15,099,288			
Domestic consumption—rural	Value (HK\$)		3,158,823	1,511,720	
	Volume (kg)		110,000	200,000	
Domestic consumption—urban	Value (HK\$)		182,207	343,207	0
	Volume (kg)		6,345	45,406	0
Quantity adjustment ( $\mu$ q)			0.528	0.227	0.183
Price adjustment ( $\mu$ p)			3.830	3.954	6.952

**Table A2.** Elasticity of live reef-fish (LRF) demand or supply with respect to prices

	Price of LRF		Per-capita fish expenditure	
	Indonesia	Malaysia	Indonesia	Malaysia
Effect on quantity of:				
Supply				
LRF—capture	0.23	NA	NA	NA
LRF—aquaculture	0.50	1.47	NA	NA
Grouper—capture	0.10	NA	NA	NA
Grouper—aquaculture	0.05	NA	NA	NA
High-value finfish aquaculture	NA	0.50	NA	NA
Urban demand				
LRF	-1.45	-1.39	1.29	0.65
High-value fish	NA	0.10	NA	Given
Demand for all other fish types	0.01	0	0	0
Rural demand				
LRF	0.01	-1.25	1.29	0.49
High-value fish	NA	0.10	NA	Given
Demand for all other fish types	-1.35	NA	NA	0

## Self-fulfilling mistake in the live reef-fish for food trade: a dynamic modelling approach

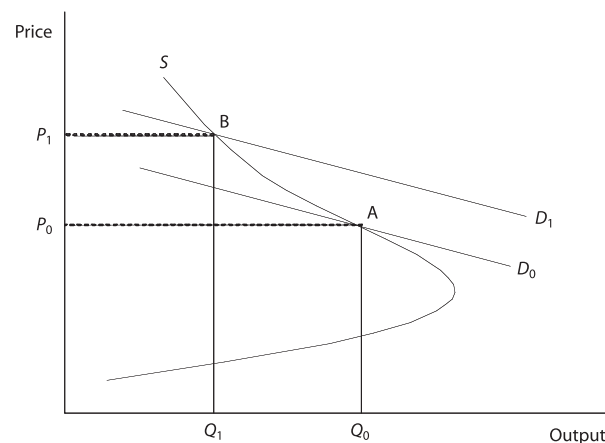
Akhmad Fauzi<sup>1</sup>

### Introduction

As elsewhere in other South-East Asian countries, fishing for live reef-fish for food (LRFF) in Indonesia has been driven primarily by continuous increase in the demand for this fish in international markets (especially Hong Kong and mainland China) as well as domestic markets. Concerns have been raised over the impact of trade in this particular type of fish on the environment as well as on the sustainability of the fishery in general. On a regional scale, Peterson et al. (2004) in their study on import demand of the LRFF acknowledge the impact of trade of this fish on the sustainability of the supply side (i.e. resources). At a national level, various studies have been conducted to analyse the exploitation of this fishery and its effect on the environment as well as on the socioeconomic aspects (Pet-Soede et al. 1999, 2004; Mous et al. 2000; Fauzi 2005). The converging theme of most of these studies is that there is growing concern about the future state of this fishery and its impact on the livelihood of the fishers and the ecosystem.

One factor that determines the sustainability of the LRFF is the ability of resources to provide a long-term supply of fish to stakeholders. It is on this issue that careful attention is needed.

A number of peculiarities arise in the case of fisheries. Since the work of Copes (1970), it is now understood that the supply curve in fishery is 'backward bending' just like the market for labour (Figure 1). In such a situation, when demand increases from  $D_0$  to  $D_1$  on the backward-bending part of the supply curve, the equilibrium moves from point A to point B, and the quantity supplied falls from  $Q_0$  to  $Q_1$ .



**Figure 1.** The supply and demand curve for a typical fishery (Copes 1972)

The backward-bending supply curve for the fishery is dictated by the biophysical characteristic of the fishery as well as the level of exploitation. The ascending part of the curve corresponds to under-exploited biomass, while the backward-bending part

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corresponds to an over-exploited biomass. This peculiarity results in a unique, dynamic behavioural supply and demand interaction. Hommes and Rosser (1998), for example, note that the backward-bending nature of the fishery supply curve is the most obvious example of a dynamic behaviour that will lead to a chaotic dynamic and self-fulfilling mistake. They also note that, combined with the open-access nature of the fishery (high discount rate) and relatively inelastic demand curve, the chaotic dynamic nature of the fishery may lead to its collapse. This finding reinforces what was initially analysed by Copes (1972), who argued that increasing demand in a fishery faced with backward-bending supply curve could lead to its collapse, as the equilibrium jumps discontinuously from one point to the other.

Studies on the behaviour of the chaotic dynamic in fishery due to the nature of the backward-bending supply curve have been exposed theoretically by Hommes and Rosser (1998), Rosser (2000) and Faroni et al. (2003). Empirical applications of this analysis, however, are few. Since LRFF has the property of a backward-bending supply curve and price fluctuations are present, these phenomena, coupled with open access and application of the myopic decision rule by fishers, make it appropriate to study the chaotic dynamic in this fishery. The approach is used to analyse the dynamic behaviour of the LRFF fishery in Indonesia.

## The models

To analyse how a backward-bending supply curve will affect the dynamic behaviour of supply and demand in the LRFF trade, this paper draws heavily from classic model of Clark (1990) that assumes a logistic function for population dynamics. Let the dynamic of fish population be given by a function of the form

$$\frac{dx}{dt} = f(x) = rx\left(1 - \frac{x}{K}\right) \quad (1)$$

where  $x$  represents population or stock in terms of biomass unit,  $r$  is the intrinsic growth rate of the population, and  $K$  is environmental carrying capacity. If harvest function is assumed to be in the form of Cobb–Douglass production function, i.e.  $h = qx E$ , where  $q$  is catchability coefficient and  $E$  is the level of effort exerted in the fishery, the population dynamic of the fishery is then written as:

$$\frac{dx}{dt} = rx\left(1 - \frac{x}{K}\right) - qx E \quad (2)$$

Solving equation (2) for a steady-state condition, i.e.  $dx/dt = 0$ , yields a unique non-zero equilibrium biomass level ( $x$ ) in terms of parameters  $r$ ,  $q$ ,  $K$  and variable  $E$ . Substituting this level of biomass into the harvest function, we obtain a yield–effort function

$$h = qKE\left(1 - \frac{qE}{r}\right) \quad (3)$$

If we define the rent generated from the fishery as:

$$\pi(h, E) = ph - cE \quad (4)$$

where  $p$  is the price of fish and  $c$  is the cost per unit of effort, the rent function can then be written in terms of harvest and biomass, instead of effort

$$\pi(h) = ph - \frac{ch}{qx} = \left(p - \frac{c}{qx}\right)h \quad (5)$$

Under open-access conditions (Gordon 1954), the total revenue will be equal to total cost at:

$$x_{\infty} = \frac{c}{pq} \quad (6)$$

$$h_{\infty} = \frac{rc}{pq} \left(1 - \frac{c}{pqK}\right) \quad (7)$$

$$E_{\infty} = \frac{r}{q} \left(1 - \frac{c}{pqK}\right) \quad (8)$$

Equation (6) is known as the open-access equilibrium of biomass, while equation (7) can be seen as the open-access equilibrium supply curve for the fishery. The curve will be backward bending at the maximum sustainable yield.

Clark (1990) introduces a theoretical capital approach to the fishery in which it is assumed that there is a 'sole owner' (a government agency or private firm) that owns the right to exploit the resource. The sole owner's objective is then to maximise discounted net revenue in the form:

$$\max \int_0^{\infty} e^{-\delta t} [p - c(x_t)] h_t dt \quad (9)$$

$$\text{subject to: } \begin{aligned} \frac{dx}{dt} &= f(x_t) - h_t \\ x_t &\geq 0, h_t \geq 0 \end{aligned}$$

Using the Euler equation and dropping time notation for convenience, the solution to the equation (9) will yield the equation (10):

$$f'(x) - \frac{c'(x)f(x)}{p - c(x)} = \delta \quad (10)$$

Equation (10) is known as the 'modified golden rule' (MGR) of fisheries management (Clark and Munro 1976) and will yield implicit solution for optimal equilibrium level of biomass  $x^*$ . Equation (10) can also be used to derive the supply curve for a sole-owner fishery. Using  $c(x) = c/qx$  and equation (1), we obtain:

$$c'(x) = \frac{-c}{qx^2} \quad (11)$$

$$f'(x) = r - \frac{2rx}{K} \quad (12)$$

Following Hommes and Rosser (1998) and substituting those equations into equation (10), we obtain the supply curve for the fishery as:

$$p = c \left\{ \left[ \left( \frac{1}{qx} \right) + r \left( \frac{1}{qx} - \frac{1}{qK} \right) \right] / \left[ \delta - \frac{2rx}{K} \right] \right\} \quad (13)$$

Hommes and Rosser (1998) explicitly solve the above supply function in terms of harvest, instead of biomass, by solving equation (2) for  $h$  to get the following supply function:

$$p = c \left\{ \left[ \left( \frac{1}{\phi} + r\phi \right) - \frac{1}{qK} \right] / \left[ \delta - 2 \left( \frac{rh}{K} \right)^{1/2} \right] \right\} \quad (14)$$

$$\text{where } \phi = \left[ \frac{K}{2} + \left( \frac{Kh}{r} \right)^{1/2} \right]$$

This supply curve will be backward bending at various discount rates ( $\delta$ ). As  $\lim \delta \rightarrow \infty$ , the supply curve will converge to the open-access supply curve since, at  $\delta = \infty$ , fishers become 'myopic', which corresponds to open-access equilibrium of Gordon (1954) and is associated with over-fishing behaviour.

For consumer demand for fish, it is assumed that it has a simple linear form

$$D(p) = A - Bp \quad (15)$$

The intersection of this demand curve with the above supply curve will yield multiple equilibria, one of which has the property of chaotic dynamic.

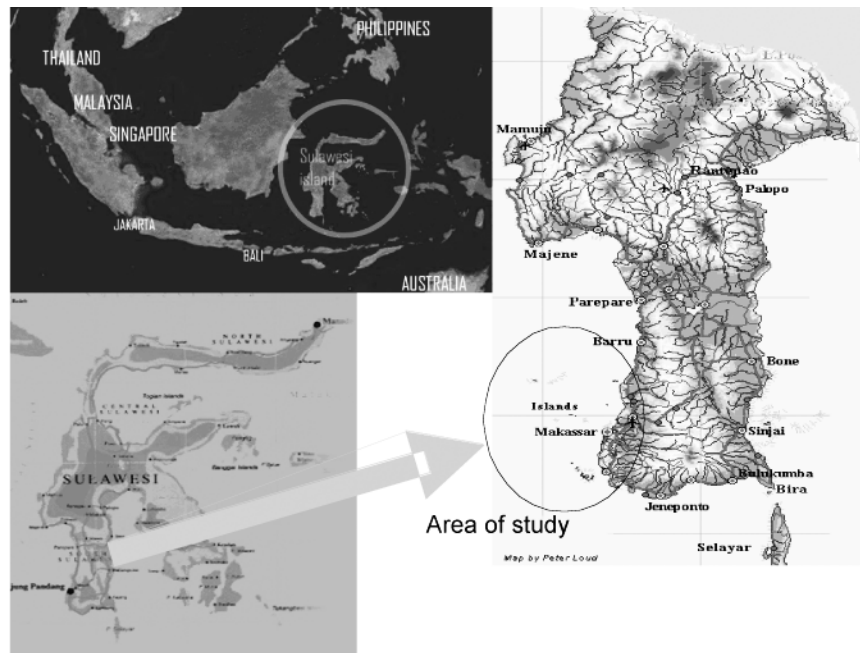


Figure 2. Map of Spermonde Island, South Sulawesi

## Application to the LRFF in Indonesia

As mentioned previously, the LRFF has the property of a finite supply curve due to limiting capacity of natural environment as a result of concavity of the logistic growth function. To derive the supply function for the Indonesian LRFF fishery, a field study was conducted in two islands of South Sulawesi, i.e. Barrang Lompo and Barrang Caddi (Figure 2). These two islands have been well known as the main suppliers of live reef-fish among 120 islands around Spermonde Island of South Sulawesi. A cross-sectional survey involving 114 LRFF fishers was conducted to determine the economic parameters of the model, while time-series data of catch and effort of LRFF from these areas were used to derive the biological parameters. Estimation of these parameters was carried out using standard OLS technique by employing a method developed by Clarke et al. (1992) which is of the form

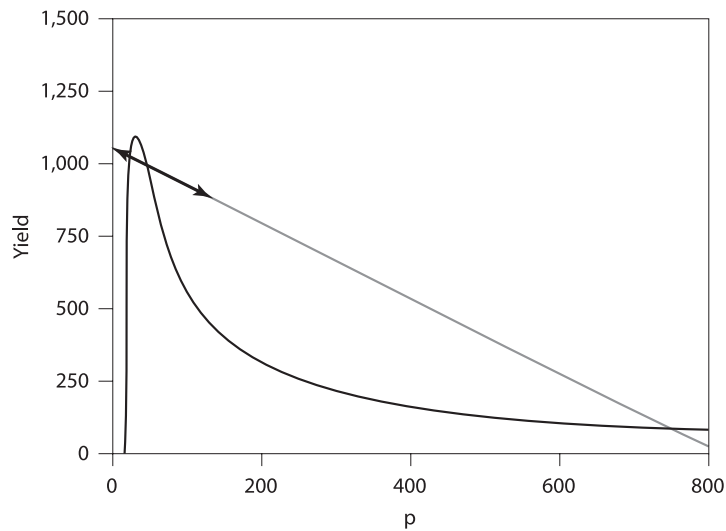
$$\ln(U_{t+1}) = \frac{2r}{2+r} \ln(qK) + \frac{2-r}{2+r} \ln U_t - \frac{q}{(2+r)} (E_t + E_{t+1}) \quad (16)$$

where  $U_t$  is catch per unit effort at period  $t$ , and  $E_t$  is level of effort exerted in the fishery. The result of calculation yields the following parameters,  $r = 0.53$ ,  $K = 8307.22$  and  $q = 7.10^{-7}$ .

Combining these parameters with economic parameters derived from the field survey, which are  $p = 40$  (Rp million/t),  $c = 0.08854$  (Rp million/trip), and varying the value of discount rates  $\delta$ , we have all parameters required to run the model. Due to the complexity of mathematical formulation, MAPLE algorithms as well as Excel algorithms were used to run the model.

To derive the demand function, this study follows the technique used by Rosser (2000), Hommes and Rosser (2000) and Foroni et al. (2003), in which the coefficient of marginal demand ( $B$ ) in equation (15) has been chosen to allow the possibility of multiple equilibria, while parameter  $A$  has been chosen such that, at the minimum price  $P_{\min} = c/qK$ , consumer demand will be equal to the maximum sustainable yield.

Figure 3 shows inverted open-access supply and demand curves with high levels of discount rates. The intersection of the supply curve with the demand curves yields multiple price (Rp'000/kg) equilibria at  $p = 20$ ,  $p = 47$  and  $p = 745$ .



**Figure 3.** Dynamic equilibrium of supply and demand for live reef-fish for food under open-access fishing conditions

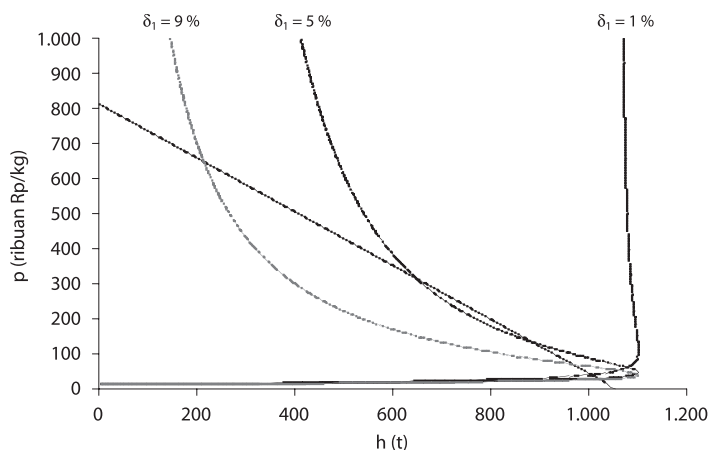
As explained in Clark (1990), the multiple equilibria will result in an instability in the economics of fishing that will tend to lead to over-fishing. Consider the equilibrium level at  $p = 47,000$  rupiah/kg. This level of equilibrium is unstable since, with any slight movement of catch below this equilibrium level, the demand curve is always higher than the supply curve, leading to an increase in price, while at the harvest level above the equilibrium, the demand curve is below the supply curve leading to a drop in price. The instability of the price level at this point is indicated by movement in arrows in opposite directions to each other.

Figure 4 shows the discounted supply curve under various values of  $\delta$  with the highest level of discount rate resembling the open-access situation.

The equilibria of dynamic price adjustment under various discount rates, as well as their stability conditions, are listed in Table 1.

As can be seen from Table 1, price level ranges from Rp40,000 to Rp136,000 indicate unstable price levels. These price levels to some extent mimic current price fluctuations in the Indonesian LRFF. This implies that the current price level will result in instability of fishing for live reef-fish. Clark (1990) refers to this situation as 'catastrophic jumps' since a relatively minor shift in the demand curve will engender a serious degree of overfishing. Clark (1985)

provides a comprehensive list of fisheries that collapsed around the world due to unstable behaviour similar to that described here.



**Figure 4.** Various equilibria under different values of discount rate

**Table 1.** Price equilibria and their stability condition under different level of discount rates

Discount rate ( $\delta$ )	Price equilibria (Rp'000/kg)	Stability
0.1	41.3	Unstable
0.5	31.5	Stable
	136	Unstable
	315	Stable
0.9	30	Stable
	70	Unstable
	650	Stable

Rosser (1998) found similar behaviour in fisheries characterised by backward-bending supply curves. He refers to this situation as 'self-fulfilling chaotic mistakes' in which economic agents cannot distinguish between randomness and determinism. In such a situation, agents may be unable to distinguish the true dynamic of the system in which they are involved. Faced with this situation, they may adopt simple, boundedly rational rules of thumb based on some sort of backward-looking adaptation. This situation occurs in fisheries, especially LRFF, where agents do not realise the catastrophic effect of their fishing behaviour and continue fishing only based on their adaptive expectations in the past.

## The dynamic behaviour of LRFF over time

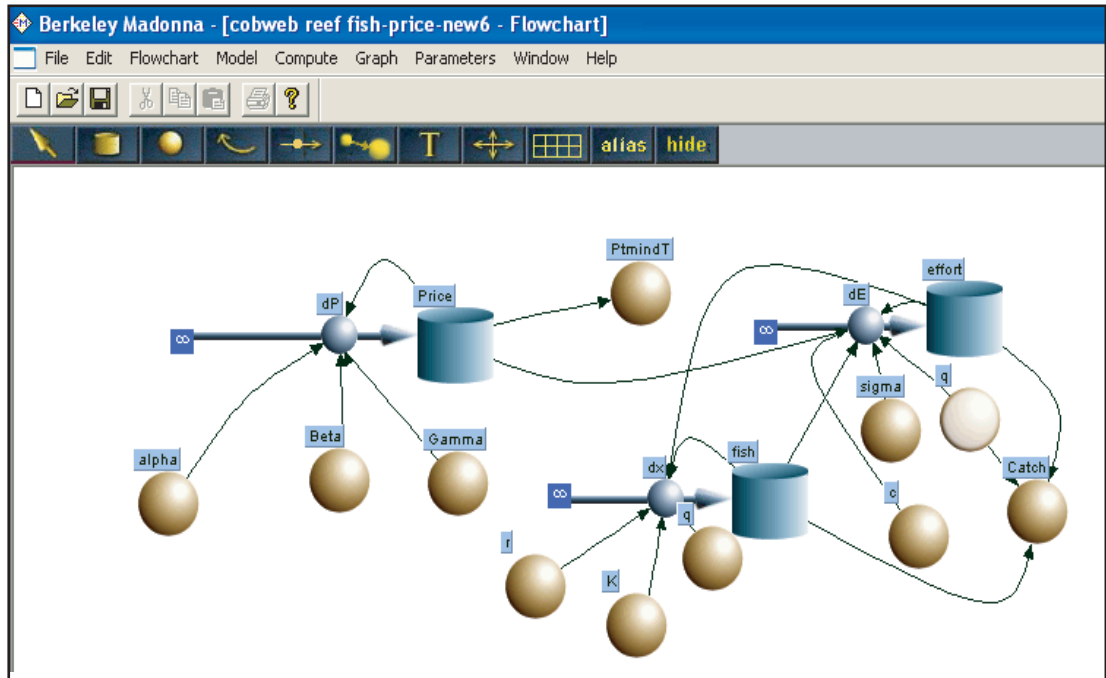
In the following section, we extend the model using system dynamic simulation as described in Fauzi (2005). Fauzi (2005) described the market-clearing condition of the Cobweb model as the following difference equation:

$$P_t = \alpha - \beta P_{t-1} + \gamma P_{t-1}^2 \quad (17)$$

Inserting this equation into the dynamic effort equilibrium  $\partial E / \partial t = \sigma(P_t q x_t - c)E_t$ , and transforming into discrete form, we obtain equation (18):

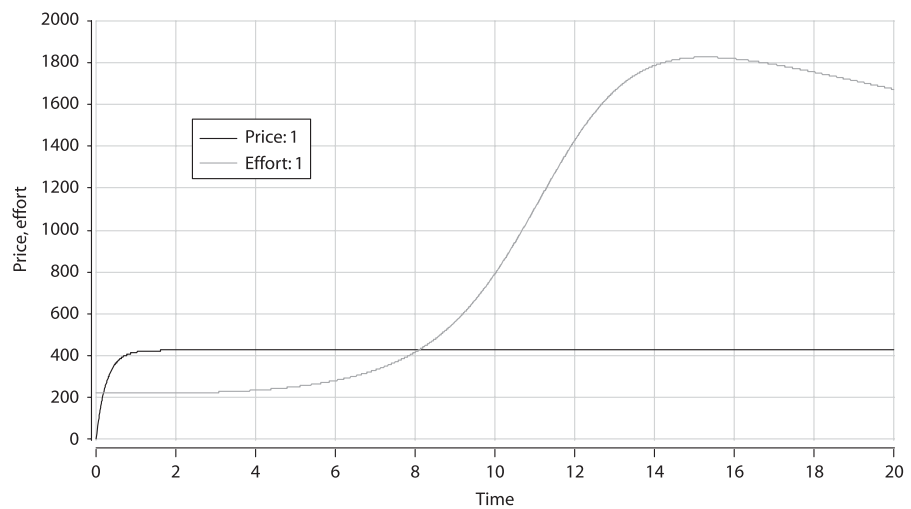
$$E_{t-1} - E_t = \sigma(\alpha - \beta P_{t-1} + \gamma P_{t-1}^2)q x_1 - c)E_t \quad (18)$$

Combining these equations with equation of motion (1) results in three, system dynamic equations. The model was implemented using the Berkeley Madonna solver and described by the iconic form depicted in Figure 5.



**Figure 5.** Iconic representation of Cobweb model for live reef-fish for food

Estimations of parameters  $\alpha$ ,  $\beta$  and  $\gamma$  from equation (17) were carried out from time-series data of prices for LRFF in South Sulawesi. Using a regression technique, the parameters estimated are  $\alpha = 1642.77$ ,  $\beta = 1.9725$ ,  $\gamma = -0.000004$ , while the coefficient of adjustment was set equal to 1.

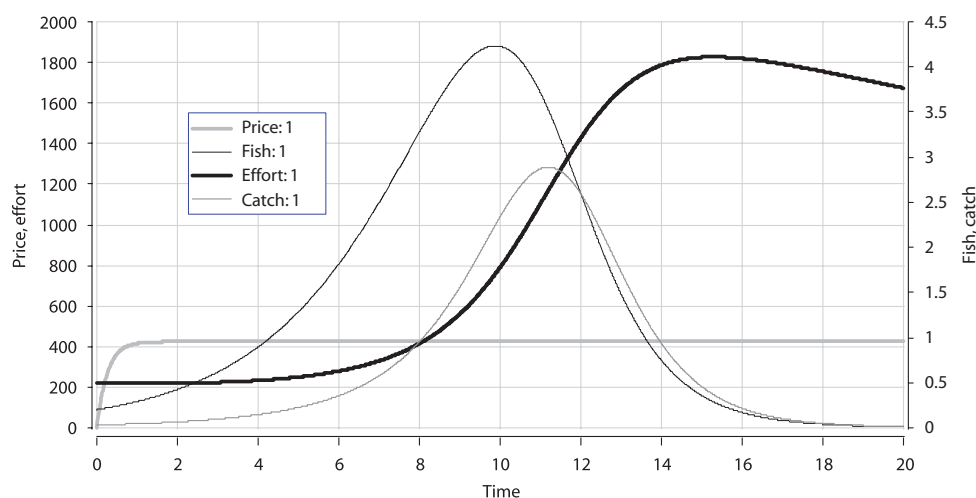


**Figure 6.** Trajectory of price and effort in the live reef-fish for food fishery in South Sulawesi

Figure 6 shows the time path of price, catch and effort of the LRFF in the area being studied. The time path of price will increase sharply in the early period and then stabilise in the long run

at Rp400,000/kg. This is significantly higher than maximum current price which is around Rp150,000/kg. However, given rising demand and a backward-bending supply curve, this price level could be reached in the long run if no control over the fishing is implemented.

Figure 7 shows the behaviour of catch, biomass and effort levels of LRFF in the area being studied. Catch and effort show a trend of increase almost exponentially up to year 10, then decline thereafter. With predicted increase in price, effort and catch levels will respond to such increases accordingly. Effort and catch will increase modestly at the beginning, and then increase rapidly in the long run. This increasing trend, however, is short-lived since once the stock level has declined, while effort continues to rise, the harvest level will decline accordingly.



**Figure 7.** Trajectory of price and effort in the live reef-fish for food fishery in South Sulawesi

## Concluding remarks

Understanding the peculiarity of the live reef-fish fishery, in particular the nature of its backward-bending supply curve, and analysing it in a more comprehensive way will undoubtedly benefit us in understanding the impact of economic activities on fishing as a whole. Continuing increase in demand for live reef-fish as food and the constraints imposed by natural productivity might lead to a catastrophic impact if no action is taken. The potential chaos, however, could be avoided if we understand the dynamic behaviour of the fishery and inform the economic agents on what to do to avoid it. With regard to the dynamic of the fishery being studied, it is worth noting that this modelling effort reinforces what is already predicted from the theories of fisheries economics and mathematical dynamics, that chaos or instability might arise due to myopic decisions by agents (as in the case of LRFF) or as a result of lack of control over access to the fishery resources. This suggests that markets and fishers should take a longer view when fishing for live reef-fish and a system to control access to the resources should be encouraged. Homes and Rosser (2000) note that the fishery could be prevented from collapsing if fishers are able to follow an underlying truly chaotic dynamic, even by doing so through a self-fulfilling chaotic mistake.

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# Policy options to improve market performance in the live reef-fish food trade

Geoffrey Muldoon<sup>1</sup>

## Introduction

Empirical research suggests that overall catches of grouper in the western Indo-Pacific and South-East Asia are at a level close to their maximum productivity (Sadovy and Vincent 2002). In some places that have been subjected to higher effort intensity and targeting of key species, catches exceed the reef or regions productivity and localised over-exploitation has occurred (Sadovy et al. 2003). The high-value live reef-fish for food (LRFF) fishery is a case in point. Ongoing demand for LRFF from key markets has exerted a large ecological footprint, taking with it a substantial proportion of the available biomass (Warren-Rhodes et al. 2003).

If it can be managed by controls on effort, the LRFF fishery has the potential to be a lucrative and sustainable fishery. The LRFF fishery in Australia is an example of a fishery regulated effectively against over-fishing through a mixture of input (gear restrictions, size limits, and spatial and temporal closures) and output (individual quotas) controls. The LRFF generally is, however, with few exceptions, largely unregulated across the extent of its impact. This type of unmanaged fishery can lead not only to the loss of important resources but also compromise future food security and socioeconomic development of dependent coastal communities (Ahmed et al. 2004). There are a number of characteristics of the LRFF trade that make effective regulation especially difficult, including:

- the artisanal or subsistence nature of the fishery
- physical (geographic and political) remoteness of fishing grounds and fish collection points from decision-makers
- limited knowledge of the status of targeted stocks
- limited monitoring and enforcement capacity of governments
- corruption and lack of political will.

In addition to regulation of effort, unique supply-chain characteristics of the LRFF trade have created market and supply inefficiencies including:

- convoluted trade relationships and vertical collusion among agents
- low technology, including fishing gear, storage and transport infrastructure.

This paper examines the range of policy options for improving market performance through both more traditional options for fishery regulation as well as alternative management approaches and interventions that recognise the unique conditions within the trade. The next section reviews fisheries management generally as it relates to the LRFF trade. The third section of the paper introduces the range of policy and management options and discusses them in terms of their merits and limitations and where along the market chain they might be targeted. The conclusion summarises the policy environment in the context of market improvements and how the policy's success, or otherwise, may be measured.

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## Fisheries management and the trade in live reef-fish for food

Most fisheries management methods require a combination of limits on area, time, gear, size, species and effort. Acceptance of these restrictions can vary for a variety of government, economic, cultural, biological and technological reasons (McClanahan et al. 2005). Prior empirical research has shown that, in reef-based fisheries, low incomes make access and effort difficult to manage, while species diversity on reefs makes species management difficult (McClanahan et al. 1997). According to McClanahan and Mangi (2004), area closures, gear restrictions and size limits remain the most amenable factors to management in reef-based fisheries.

Overfishing and destructive fishing are recognised as the two most significant human-induced threats to the sustainable management of coral reefs (Burke et al. 2002). The major issues concerning the LRFF trade are overfishing—including destructive fishing, targeting of juveniles and fishing of spawning aggregations—and the social and economic implications of this overfishing to adjacent coastal communities (Sadovy et al. 2003; Ahmed et al. 2004). An outstanding question with regard to managing LRFF fisheries is whether the enterprise of LRFF fishing can be profitable when kept on a scale consistent with the limited productivity of the resource, and whether the public management costs needed to keep the fishery within those bounds would be prohibitive.

Most countries do not have a management strategy specifically for their LRFF fisheries and, in countries where the trade in LRFF is well established, the fishery is either managed ad hoc or not managed at all. In most countries, LRFF fisheries have expanded alongside existing subsistence and artisanal fisheries, such that LRFF fisheries cannot be viewed in isolation, adding further difficulties to their management and regulation.

A key impediment to the effective management of LRFF fisheries is the paucity of data available. This is compounded by the fact that the trade has expanded rapidly, targets a diverse range of species, uses multiple fishing gears, involves many fishers, and is spatially dispersed (Pauly 1999). Despite the economic importance of LRFF species, there is limited biological information to enable stock assessments and therefore determination of sustainable levels of harvest. Catch data are likewise rarely collected and where they are, with few exceptions, the data are coarse and highly aggregated across species. Where monitoring and reporting of exports and imports are undertaken, the reliability of these data is generally questionable. Aside from misreporting of species and inclusion of non-live reef-fish in export data, 'official' data tend to under-report because of the physical remoteness of fishing areas and the use of live-fish transport vessels. The latter results in fish movements being unrecorded both leaving the source country and upon arrival in Hong Kong.

The lack of institutional capacity in a fishery where catches are landed over a substantial coastal area exacerbates the problem of collecting catch statistics and impedes implementation of management reliant on those data. Moreover, the spatial scale at which fishing takes place means the data collected are often inconsistent with ecosystem boundaries (Sadovy 2005). Current data limitations and impediments to the future collection of data needed for stock assessments within reef-based fisheries have led to calls for 'data-less management' approaches to be adopted. These approaches operate on the tenet that sub-optimal management based on incomplete data are superior to no management at all (see Johannes 1998).

Efforts to implement fisheries management plans in LRFF fisheries can founder for a variety of interrelated reasons including low incomes and poverty, heavily populated coastal zones, intense competition for already depleted resources and a lack of alternative livelihood options. These pressures, combined with a lack of enforcement and monitoring capacity and

a lack of political will by governments to impose and enforce regulation, encourage non-compliance by fishers and traders alike and remain a barrier to successful management of LRFF fisheries using conventional management tools. Overcoming conflicts of interest and corruption within community authorities and all levels of government are often among the most important management challenges.

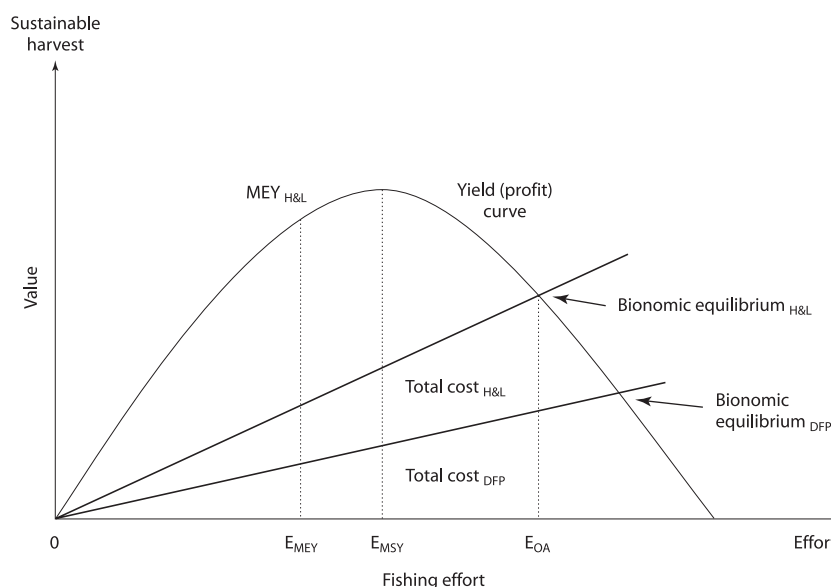
In some ways though, LRFF fisheries are quite different from reef fisheries in general and this can both assist and hinder their regulation. LRFF fisheries generally target fewer species than traditional reef fisheries, while the 'live' nature of the product, the low gear technology and limited fishing range tends to lead to more spatially concentrated fishing activity around collection points (Pet Soede et al. 2001). Movement of fish along the market chain within supply countries must traverse major collection points, while exports are often funnelled through a few major hubs and imports enter demand markets through even fewer points. These bottlenecks suggest that enforcement could be exercised at key points along the market chain. On the other hand, the long distances of some fishing grounds from administrative and governance centres, and markets, and the large number of subsistence-level participants remain difficult obstacles to overcome.

A high priority should be put on curbing the use of destructive fishing methods and promoting the use of hook-and-line techniques. In encouraging the use of handlines, the main obstacle is that much of the region is already over-fished and showing catch-rate declines. Curbing the destructive fishing practices of the trade is also hampered by governments complicit in the trade (Pet and Pet-Soede 1999).

Many reef-based fisheries, such as the LRFF fishery, are likely to be operating at a bionomic equilibrium where net profits are zero and fish stocks are heavily overfished (Figure 1). Studies suggest that the maximum economic yield (MEY) for these fisheries is at ~40% of bionomic equilibrium, implying effort reductions in the order of 50–60% of current levels are needed (McManus 1996). In fisheries such as the LRFF fishery, there are few if any economic constraints on effort. Fishing gears are inexpensive and simple, and the opportunity cost of a fisher's labour is close to zero. The possibility of a catch of any sort is sufficient for continued exploitation up to, or even beyond, bioeconomic equilibrium (Munro 1996). This abundance of low-costs labour gives some insight into the unique problems faced by reef fisheries. The use of destructive fishing practices such as cyanide (Bentley 1999) that increase catch rates, effectively lowers the cost of fishing, generating scarce profits. These profits are likely to be short lived as more existing fishers adopt destructive practices and others are attracted to the fishery, resulting in a further lowering of the bioeconomic equilibrium. This cycle has led to the occurrence of 'Malthusian' over-fishing in many reef-based fisheries of South-East Asia.

While the range of conventional management options can be applied to LRFF fisheries, the lack of in-country enforcement and monitoring capacity undermines their effectiveness in reducing over-fishing. Consequently, a range of policy options and regulatory tools, some which may be unique to reef fisheries generally and LRFF fisheries in particular, is being explored and advocated as alternatives to conventional management. These include alternative livelihood programs, mariculture, and spatial or temporal closures. Mechanisms for improving supply-chain effectiveness (e.g. husbandry and transport) are also worthy of investigation. The creation of alternative livelihoods that reduce fishing pressure is an onerous undertaking that requires consideration of viable and suitable alternative livelihoods as well as the local economic, social and political climate. Alternative livelihood programs can be successful only where they have community support and offer better returns and a better quality of life than the activity they replace. Full-cycle mariculture of grouper or other marine organisms is a farming example, while ecotourism offers a means of alternative or additional income. With the failure of conventional regulatory approaches,

marine protected areas (MPAs) are being increasingly advocated as a management tool in reef fisheries to curtail the depletion of fisheries resources (Bohnsack 1998; Russ 2004; Sale 2002). While protected or no-take areas may be easier to enforce than size limits or gear restrictions, their success again hinges on community support. Lastly, coral reef resources are undervalued in terms of their social and economic worth.



**Figure 1.** Fixed-price model of a fishery showing effort allocation at maximum sustainable yield (EMSY), maximum economic yield (EMEY) and bioeconomic equilibrium (EOA) for a hook-and-line (H&L) fishery. Where destructive fishing practices (DFP) are employed and improve catch rates, costs are lowered, leading to a new bioeconomic equilibrium with increased effort.

Development of a sustainable LRFF fishery requires management measures to be targeted along the market chain (i.e. fishers, traders and/or consumers). Correspondingly, there are two approaches to regulating the LRFF trade:

- fisheries management per se, i.e. managing fisheries by limiting their size (quantities and type of fish taken) and scope (areal and/or seasonal fishing closures)
- market-based reforms such as demand-side and trade controls using national, regional and international mechanisms, influencing consumer behaviour through outreach, and agent behaviour through codes of best practice and industry standards.

## Policy options for management of the trade in live reef-fish for food

The management of reef fisheries requires local solutions aimed at maintaining their sustainability but within both a regional and global context (McClanahan 2002). For example, restrictions on trade in reef species such as LRFF can be strengthened through global initiatives, while at a regional and local level sustainable management of LRFF fisheries can be achieved through restrictions on space, species, gear and effort.

White and Courtney (2004) group coral reef management policies into three categories across local and national or global scales—governance, regulatory limits on access and use of economic incentives. Marine protected areas are a governance policy that span local and national/global spheres with the former being community-based and site-specific, while the latter encompasses the notion of 'networks' of MPAs that operate at either a national or trans-

boundary scale. Similarly, best-practice and certification systems, which are most visible at the global levels, will be effective only where they are strengthened by national regulations and have local support. Regulatory mechanisms are many and yet, within reef fisheries, few are successful in achieving their intended objective. At a local level, regulatory policies almost always limit access and use but, to be effective, they must be accepted by communities. On a national/global scale, local regulation can be strengthened by international trade agreements such as the Convention on International Trade in Endangered Species (CITES) and national policies that control exports of internationally traded species. Moreover, according to White and Courtney (2004), national level regulation that accords with local activities can make for more effective enforcement.

With this in mind, policies for regulating the LRFF fishery and/or improving its market performance may be considered as falling under one or more of a number of key areas. These include:

- fisheries management that improves economic outcomes through effort and catch regulation and strengthening of resource ownership
- technology improvements that reduce costs of producing and marketing LRFF—costs may be reduced through efficiency improvements (i.e. economies of scale) or improvements in handling, storage and transportation that reduce risk of mortality
- technology that enables the production of alternative supply sources from aquaculture, including hatchery, grow-out and environmental considerations
- identifying inefficiencies and distortions along the marketing chain and means by which these can be overcome to improve market performance and to ensure fishers receive a fair economic return (cooperatives, horizontal integration)
- initiating or facilitating shifts in demand and supply<sup>2</sup> through influencing consumer preferences and through market-based mechanisms (e.g. standards and best practices).

## Traditional management options of the trade in live reef-fish for food

The key issue for the LRFF trade in the Asia–Pacific region is controlling fishing effort and catch, and the methods by which fish are caught. This can be done through a range of conventional direct and indirect management approaches (Figure 2). Their suitability for LRFF fisheries will be determined by local and national economic, social and political considerations. These management options can be grouped into controls over inputs, incorporating destructive fishing practices, and controls over outputs.

Where asked for information on the management of a potential new fishery, and given this background, we suggest the following precautionary guidelines for the first year of development of a LRFF fishery.

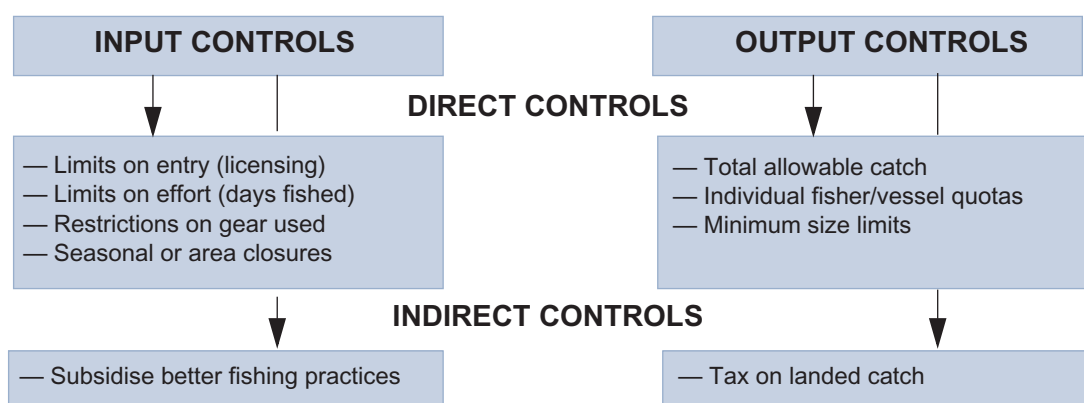
### Licensing

While licensing of fishers and/or foreign operators is one of the strongest mechanisms available to manage LRFF fisheries, in that it can recognise reef ownership, create resource rents, control the intensity and location of fishing activities, impose reporting requirements and recover costs through license fees, it also the most foreboding. The prospect of issuing licenses and maintaining a licence program for many hundreds or thousands of subsistence

<sup>2</sup> Shifts may arise due to forecast changes in future consumption and production, technology changes that reduce production costs, income growth, changes in fisheries regulatory policy and changes in other government policy.

fishers is limited. Moreover, where licensing programs do exist (Fiji, Indonesia, Papua New Guinea and the Philippines) their effectiveness has been hindered by (Sadovy et al. 2003):

- a lack of cohesion between various tiers of authority
- the need to negotiate licensing agreements with traditional owners, in conjunction with provincial or national government, where customary marine tenure prevails.



**Figure 2.** Direct and indirect input and output controls for managing fishing effort and catch

License agreements between owners and traders can be used to both safeguard the resource and negotiate ‘equitable’ returns on resources extracted. In reality, however, despite instating licence agreements, disputes often arise between traditional owners or municipal leaders that erode their effectiveness (Sadovy et al. 2003).

Licensing may be more effective when targeted at buyers or exporters. Currently in several countries, as a condition of being granted a license, exporters are required to maintain and submit records on the number and species of fish exported. In the Philippines, for example, the export and transport of fish and fisheries products require permits from the Bureau of Fisheries and Aquatic Resources (BFAR). Even so, there are deficiencies with the program. Permits must be approved before the consignment of LRFF can leave the country. Any lag in processing will interfere with the perishable nature of the product and so exporters circumvent these conditions by submitting ‘estimates’ to BFAR well ahead of actual shipment<sup>3</sup>, suggesting that any data on LRFF production from the Philippines will likewise be overestimates. For data-collection purposes, a system of real-time reporting or post-hoc reporting would be preferred. Licences have also been used in some producer countries to allow for ‘trial fisheries’ to proceed under strict and closely monitored conditions<sup>4</sup> and grant permission to fish commercially or to export fish for the specified trial period. The effectiveness of any licensing program, including trial fisheries, will depend on the level of cohesion between and enforcement capacities of various tiers of authority.

<sup>3</sup> Benzon Cheng and Kenneth Vy, pers. comm.

<sup>4</sup> Management measures include total allowable catch limits, use of handlines only to capture fish, restrictions on holding-cage size and placement, size limits on target species, exclusion from known aggregation sites, fishing to take place in designated fishing areas, and monitoring and reporting controls.

### **Effort restrictions**

Restrictions on effort may take the form of reducing the total number of fishers in a fishery, limiting or capping the number of days fishers are allowed to fish, or restricting where effort may be applied spatially. The success or otherwise of effort reductions will be severely hampered by the subsistence nature of the fishery. The elasticity of supply (i.e. labour) in the LRFF fishery is low (Liese et al. 2003) and many fishers are likely to already be fully engaged in the fishery. Where any success in effort-reduction programs might lead to an increase in catch per unit effort or fishery rents, the open-access nature of the fishery and the lack of alternative livelihoods will encourage the entry of new or re-entry of old fishers. A lack of enforcement capacity at a local level in most of the Asia-Pacific countries, and the remoteness and spatial extent of fishing grounds, means controlling the expansion of effort will be limited.

### **Gear restrictions**

Input controls that regulate fishing by permitting specific fishing practices, such as hand-lining, and prohibiting others, such as cyanide fishing and fish traps, are easy to advocate but decidedly more difficult to implement effectively. In all countries engaged in the trade, hook-and-line techniques are widely practised, but usually alongside destructive fishing techniques. Despite the most active countries in South-East Asia specifically having national and provincial regulations that prohibit the use of cyanide (Bentley 1999), the practice remains widespread.

Outreach and training efforts have been undertaken in many areas to induce fishers to switch to non-destructive gears but there are clear obstacles to their take-up. Cyanide has been shown to be a more efficient capture technique in terms of the numbers and average size of fish caught (Bentley 1999). In locations where fish stocks have already been depleted and fishers are operating at subsistence levels, the incentive to replace cyanide fishing with more benign techniques that reduce catch rates is low. Other gear regulations that may be useful for the trade include modifying the selectivity of gears (i.e. minimum hook sizes, fish traps) so that larger fish are selected, and introducing, perhaps through subsidies, more effective baits such as fresh fish.

Gear restrictions are often effective in the context of local management or when used in conjunction with MPAs (i.e. no-take zones). Given that regulations on gear must be targeted at the supplier, compliance will be very difficult to monitor over large areas due to limited enforcement capacity.

Theoretically, changes to fishing gears that can reduce the harvesting of immature fish will enhance future harvest potential and likely lead to increased returns to fishers who are often operating at, or just above, subsistence levels. The open-access nature of the fishery and limited enforcement capacity, however, raises the spectre that any above-normal rents will be dissipated in the longer term as fisher numbers increase.

### **Zoning**

Zoning, in the form of MPAs can control the distribution of fishing effort through seasonal or permanent closures. Marine protected areas have a long history on coral reefs in South-East Asia (Russ and Alcala 1999) and are growing in their influence in the Pacific (see Roberts 2001). In the wake of the failures of more conventional fisheries management, MPAs are being more widely advocated as an appropriate fisheries-management tool for coral-reef fisheries for protecting spawning aggregations, and acting as harvest refugia (McClanahan and Mangi 2001). Moreover, MPAs can generate positive economic effects where they enhance fishery catches in adjacent fisheries through spillover effects (Russ and Alcala 1996; Sale 2002).

Marine protected areas have been successful only where they have had high community and local government support (Pomeroy 1995). Modelling suggests that initial falls in income where MPAs are introduced are less than for other forms of regulation, increasing their likelihood of success (Martin-Smith et al. 2004). Oftentimes, however, the introduction of large no-take areas is not socially or politically acceptable in areas where fishing intensity is high and opportunities for alternative livelihoods are limited (Russ 2002). Lastly MPAs are seen to have advantages over other fisheries-management tools in that educating stakeholders is more straightforward.

### **Catch quotas**

A conflict in many of the fisheries of the Asia-Pacific region is the expectation that they will continue to contribute to the increased national production through increased total catch (Mous et al. 2005), despite most fisheries in the region being fully or over-exploited (Burke et al. 2002). Policies that encouraged export-oriented production without effective management have led to the depletion of fish stocks in many South-East Asian countries (Padilla et al. 2003).

Catch quotas are not enforced in any of the countries currently engaged in the LRFF trade, with the exception of Australia. Although LRFF fisheries target relatively fewer species than more-common artisanal fisheries, output controls such as quotas are usually impractical in tropical, inshore multi-species fisheries that support LRFF fisheries because of the limited biological and ecological knowledge of the target species (Munro 1996). With little available in the way of population assessments of grouper species, suggestions have been that data-less management (Johannes 1998) or rules of thumb (see Polunin and Graham 2003) can be applied. Rules of thumb have been proposed, although not formally adopted for the LRFF trade, to guide harvest limits in the absence of usable baseline and historical data (see Box 1) (Muldoon and Scott 2004).<sup>5</sup> These rules of thumb are intended for both new or developing, as well as existing, fisheries, although their application to the latter is made more difficult because fish stocks are heavily depleted. Even if a sensible total allowable catch (TAC) could be imposed for a LRFF fishery it appears unlikely that a TAC could be successfully enforced given the common property nature of the resource, the large number of subsistence-level fishers active in the fishery and the limited management and monitoring capacity (Pomeroy and Carlos 1997).

While imposing total allowable catches at the level of the fisher may be impractical, allocating quotas to the much smaller numbers of exporters may facilitate a flow-on effect down the market chain (see Export controls). Where an exporter has only a limited quota they would supply the market so as to maximise their returns. The perishable nature of live fish and exporter-driven demand may encourage a more discerning supply of product from the fisher. Because of the subsistence nature of the LRFF fishery and the lack of alternative livelihoods, however, supply is highly inelastic and, consequently, fishers may not reduce effort, but rather seek to redirect their catch to domestic or non-live markets.

### **Export controls**

Export controls, as the name suggests, are aimed at producer-country exporters along the supply chain. Export controls may be considered a form of quota that can be applied to producer-country exporters or, as is the case with many reef fisheries such as the LRFF, foreign vessels that collect shipments from within country waters. Similar restriction can apply to imports in demand markets. In both Indonesia and the Philippines, regulations requiring live-transport vessels to have permits before entering local or national waters have proven ineffective.

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<sup>5</sup> And that recognise in-country limited assessment, management and monitoring capacity.

Export and import controls fall under the banner of regulation of trade and, within the LRFF trade, are used to protect the more vulnerable LRFF target species by prohibiting their trade, or permitting trade of some species only under international guidelines (e.g. CITES). These conventions don't necessarily guarantee a more sustainable harvest of one or a suite of LRFF species. For example, the humphead wrasse was listed in Appendix II of CITES in October 2004 but, in the case of Indonesia, their quota is only slightly lower than average annual exports over the past several years.<sup>6</sup> Moreover, juvenile wrasse continue to be exported to markets in Hong Kong, thereby eroding the future harvest potential of this species. According to White and Courtney (2004), controls on exports will be more effective when national-level policy is in place that facilitates enforcement at the local level. This presupposes that enforcement capacity at a local level is adequate which, evidence shows, is not the case in many Asia-Pacific countries.

**Box 1.** Rough rules of thumb for the instatement and development of a LRFF fishery

Where asked for information on the management of a potential new fishery and given this background we suggest the following precautionary guidelines for the first year of development of a LRFF Fishery

- The mandatory collection of scientific information, that comprises:
  - fishing effort, recorded as a standardised measure (e.g. days fished)
  - catch data, recording length and weight at a species level
  - biological data (i.e. otoliths and reproductive organs). Otoliths will need to be collected from a minimum of 100 individuals of each species for age-frequency distribution analysis and to determine maximum age of targeted species.
- Do not harvest the longest-lived species, threatened or ecologically important species, and species recognised as important to tourism. These include but are not restricted to:
  - *Cephalopholis* spp. (e.g. *C. argus* (rockcod))
  - small *Epinephelids* spp. (e.g. *E. bleekeri*, *E. malabaricus*, *E. tauvina*)
  - humphead wrasse (*Cheilinus undulatus*).
- Limit harvests to more productive species such as *Epinephelus fuscoguttatus*, *E. polyphkiodon* and *Plectropomus* spp.
- Employ a program based on comprehensive underwater visual census to estimate standing stocks of each species and investigate changes in standing stocks in appropriate habitats.
  - UVS-based harvest limits should be set at a recommended fraction of natural mortality (e.g. ~20%). Thus, with natural mortality of  $\sim 0.3 \approx 26\%$  per year, harvests should be limited to a maximum of 5% of standing stocks per year.
- A maximum age for certain species that is lower than empirical estimates for that species may indicate catch levels of those species are excessive and a more precautionary approach to their exploitation should be enforced.
- Recognising existing marine tenure arrangements, ~30% of the available reef area should be closed to exploitation by the LRFF trade.
- The exploitation of spawning aggregations should be prohibited and the use of seasonal closures is recommended.
- Data should be collected from fishers engaged in artisanal or subsistence fisheries and the LRFF fishery (paybooks).
- A substantive analysis of community social costs and economic benefits (benefit-cost analysis) should be undertaken for all developing LRFF fisheries.
- Regional species-specific price data for LRFF species should be made available to supply countries.

ANY SPECIFIC NUMBERS RECOMMENDED SHOULD BE USED WITH CAUTION

<sup>6</sup> See Hong Kong Census and Statistics Department, and Agriculture Fisheries and Conservation Department.

### **Fish size limits**

Minimum-size restrictions are a common fisheries-management tool, often used in conjunction with other regulatory measures. Establishing a minimum size greater than the mean size at first reproduction may have a high probability of increasing stock size (Martin-Smith et al. 2004). Effective enforcement of minimum-size policies should lead to an increase in stock size and an improvement in rents extracted from the fishery. As noted previously, however, any economic benefits arising from regulatory changes will likely be eroded in the longer term because access to LRFF fisheries across the region is generally unrestricted.

Establishing minimum sizes for each species within the LRFF trade is difficult for a number of reasons, most notably an absence of biological data for all but a few species and countries. With the exception of the Philippines, an absence of biological data has meant size-limit recommendations are based on a combination of known biology of specific species and market requirements. Most high-value target species of the LRFF trade are found over a wide geographic range, but setting regional-scale size limits for those species where biological information exists for that species in one area is highly problematic (Pears 2006).

In some countries where LRFF fisheries are in operation, regulations exempt fishers from minimum-size regulations where the fish are captured as juveniles and grown-out to market size, which may or may not be less than size at first maturity. This practice undermines minimum-size legislation, as fish being held for grow-out are unlikely to have had the opportunity to reproduce (Sadovy and Vincent 2002). Any policy on minimum-size limits will need also to exclude juvenile grow-out from harvest to maximise any potential economic benefit to fishers. Given the current lack of production capacity of hatcheries to produce fingerlings for grow-out, many LRFF fisheries continue to rely on juvenile capture. Two other ACIAR projects<sup>7</sup> are focused on increasing the hatchery capacity of LRFF species in participating countries.

## **Technological improvements in handling, husbandry and transport**

### **Reducing mortality through better handling and husbandry**

Keeping the catch alive and healthy is obviously an important objective in a live-product supply chain. Poor holding and husbandry practices, which persist in many source countries, is an aspect of the LRFF trade requiring attention. Poor handling husbandry and transportation practices have been estimated to cause mortality rates as high as 80% for wild-caught fish, although estimates of between 30–50% are probably more accurate (Sadovy and Vincent 2002). The persistent use of sea transport to deliver LRFF to markets requires fish be held in floating cages for long periods after capture. Mortality during this holding phase has been estimated to be as high as 50%, with estimates of up to 30% mortality during the first 3–5 days of captivity. The economic and biological costs of holding the catch for long periods, including feeding costs, are much higher where sea transport is used (Sadovy et al. 2003).

Changes in husbandry and transport technology (see below) have resulted in lower rates of mortality along the market chain between exporters and importers. Improvements in cage design and siting, disease prevention and feed are being implemented across the region through regional agencies (e.g. the Network of Aquaculture Centres in Asia-Pacific and the Secretariat of the Pacific Community) and non-governmental organisations (NGOs, e.g. The Nature Conservancy, Marine Aquarium Council). The long-term success of such initiatives

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<sup>7</sup> Project FIS/1997/073 'Improved hatchery and grow-out technology for grouper aquaculture in the Asia-Pacific region', and FIS/2002/077 'Improved hatchery and grow-out technology for marine finfish aquaculture in Asia-Pacific region'.

depends upon the capacity and willingness of countries to support the programs in the absence of external assistance. Wider adoption of best practices and uptake of improved technology that reduces mortality at all stages of the market chain from fish capture through to restaurants are essential to improving the market performance of the trade.

### Mode of transport

LRFF are delivered to consumer markets using either sea or air transport. For many years, sea transport was the preferred means of shipping LRFF but, as distances between fishing grounds and markets increased and new technology became available, shipping fish by air has become more widespread. In some of the main exporting countries – Indonesia, the Philippines and Australia – shipments by air carry approximately 50%, 70% and 100%, respectively, of total exports (Sadovy et al. 2003).

Fish survival is partly a function of the time it takes to get the fish from the point of capture to the point of export. Where sea transport is used to deliver LRFF to markets, fish are held in holding pens for long periods until sufficient volumes have been consolidated to make sea transit cost-effective.<sup>8</sup> While costs of shipping fish by sea often compare favourably with shipping by air (Muldoon and Johnston 2006), mortality during sea transit, which can take 1–2 weeks, can be as high as 15% (P. Chan, pers. comm.). Moreover, large, live-transport vessels have a minimum profitable payload of up to 10–15 tonnes of fish. This can lead to long-term economic losses in producer countries through localised over-exploitation of stocks and may oversupply the market, driving down price and eroding profits to the live-fish trader. Some countries engaged in the LRFF trade regulate the conditions under which the fish are transhipped, such as requiring loading of catches to take place from designated ports or banning the use of live-fish transport vessels (see Export controls).

Air transport is becoming more widely used. Fish are shipped by air using one or other of two technologies: highly oxygenated plastic bags held in small polystyrene boxes (4–6 fish/box) and large fibreglass oxygenated transport bins capable of holding 300+ kg of fish. The wider adoption of special transport bins to freight fish by air is reported to have reduced fish mortality rates considerably. Holding times in source countries have been reduced, thus lowering holding mortality, while mortality during transshipment times can be less than 5%.<sup>9</sup>

Governments of some countries (e.g. Australia) can, where there is ample frequency of flights and reasonable shipping rates, require live fish to be shipped by air. Limited infrastructure and cost prohibitiveness in many countries precludes the shipping of fish by air, using either of the two technologies noted above. The absence of air-transport options and the distance to market by sea may have contributed, on financial grounds, to the irregular exports of LRFF – effectively a proxy output control – such as in the Pacific, but also may have served to protect LRFF target fish stocks from the over-exploitation that has occurred in South-East Asia.

The ability to create a transportation system that would make air transport of LRFF economically feasible is limited; however, trends in air transport may change over time, as might technologies for transport of live fish. The supplanting of traditional sea with air transport, in addition to lowering mortality, will reduce holding costs and risk of investment for traders. Economic incentives (e.g. subsidies) that lower air-transport costs should be

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<sup>8</sup> An important constraint for operations that ship by sea is that large amounts of fish (10–20 t, depending on the distance) must be shipped in order to make the trip cost-effective. Note that shipments from producer countries closer to consumer markets can be as low as 3–5 tonnes.

<sup>9</sup> Holding times for LRFF sent by air are approximately 7–10 days from first sale, including reconditioning fish during transit, as compared with upward of a month for LRFF sent to market by sea.

considered in terms of their socioeconomic and biological costs, and benefits of reduced mortalities and potentially lower ecological impacts.<sup>10</sup>

### **Alternative production technology improvements**

At present, the role of production technology improvements in aquaculture is limited because, although the volume of production through aquaculture is large (more than 20,000 t per year), the majority of small fish that are grown-out consists of wild-caught fish. There are clearly roles for regional/international organisations in broader aspects of managing the trade. While hatchery technology is advancing rapidly (Sadovy et al. 2003), the availability of commercial hatchery-reared fingerlings is still not able to meet demand. As technology improves, only selected LRFF species are likely to be available and there is little prospect for large-scale production of high-value, high-demand species such as humphead wrasse and leopard coralgrouper in the short term (Sadovy et al. 2003).

There has been some use of hatchery-reared fish, including grouper species, to 'seed' reefs in South-East Asia, in an attempt to restore over-exploited fish populations. The effectiveness of restocking is largely unknown in terms of survival and ecological adaptation (Roberts et al. 1995) and little assessment has been done on the impact of stocking on wild populations or on timing and location of release (Bohnsack 1996).

Aquaculture can be considered an alternative livelihood, but there are many constraints to its suitability in this regard for poor fishers. These include technology, capital intensiveness and long-term payback characteristics of grouper farming, the difficulty of persuading fishers to change vocations, the difficulty and seasonality of maturation and larval rearing, the shortage of suitable sites, the reduction in demand for wild seed limiting existing livelihoods, and limitations on market access (Briggs 2003). Even so, aquaculture does present an opportunity to break the cycle of indebtedness but requires government and NGO support through the provision of capital (mainly revolving funds), education and capacity building.

Any increase in the production of LRFF species need not be considered in terms of the potentially lower price from increased supply of cultured species and the difference in product quality between cultured and wild-caught species. The latter is perception-driven and will depend on the acceptance by consumers of cultured fish as a substitute to wild-caught fish (see Consumer preference below)

## **Identifying inefficiencies along the marketing chain**

### **Market transformation**

In the case of live reef-fish fisheries it has been suggested that fishers are usually poorly paid based on the final value of seafood products (Wood 2001). There are several factors that would explain this, such as remoteness of fishing grounds, low storage and gear technology, and the need for an extended market chain. Moreover, the financial risk borne by agents further along the chain is considerably higher: costs of transportation are high, relative to the value and volume of shipments of fish (Muldoon and Johnston 2006). Transforming the market chain to realise more 'equitable' distribution of the final value of the fish may come in the form of several initiatives, some which have been referred to previously.

- Improved husbandry practices and transport technology that lowers mortality during storage and transit and hence per unit (fish) costs of transport could be adopted. These savings may flow through the chain.

<sup>10</sup> With fewer fish required per shipment, opportunities for a small-scale fishery that is both economically and ecologically viable present themselves.

- Market chains could be restructured to benefit small-scale fishers, although opportunities to do this appear to be limited (MacFadyen et al. 2003). Horizontal integration where adjacent communities or aquaculture farms form cooperatives could enhance bargaining power and lead to improved returns.
- The perishable nature of the LRFF product lends itself more to vertical integration along the market chain. There is a need for improved flow of, and increased access to, market information along the product chain. Opportunities for vertical cooperation are likely to be greater in finfish aquaculture due to its ability to meet variant demand and exercise quality control (van Anrooy 2003).
- The small number of exporters and importers suggests that opportunities for market transformation exist through partnerships between demand and supply countries, either informally through stakeholder agreements, or formally through government channels. The prospect of either seems distant, because traders show reluctance to accept an active role in promoting responsible fishery practices (Cesar et al. 2000).

### **National, regional, and international mechanisms**

The Hong Kong Government has taken a positive step in regulating the trade by revision of the harmonised code to facilitate monitoring of imports, and has begun to discourage destructive fishing practices via a program of education, monitoring and enforcement. Development of a regional LRFF trade agreement through the Asia-Pacific Economic Cooperation forum (APEC) would likely be of limited success, because APEC is not a negotiating body. A multilateral approach by affected APEC supply economies, however, could encourage the Hong Kong Government to strengthen its enforcement activities against destructive fishing practices in producer countries.

### **Collaborative-management models**

Collaborative-management approaches are being seen as playing a vital role in fisheries management (Martin-Smith et al. 2004). Involving stakeholders in decisions affecting the fishery is seen as increasingly important for successful management of fisheries resources (Pomeroy and Katon 2001). One suite of collaborative approaches that is becoming more widely accepted is the use of common principles and standards of best practice as a means to conserve resources, regulate product quality and promote more responsible trading to the benefit of small-scale fishers. A number of different collaborative models based on such standards and principles have been proposed for achieving improved resource management, including the following.

The International Standard for the Trade in Live Reef Food Fish was developed in 2004 with endorsement from all APEC economies. As a voluntary document, the standard is not ascribed the same level of credibility and acceptance by end users and governments as voluntary codes of conduct or certification schemes. Codes of conduct provide frameworks for coordinated national, regional and international efforts relating to sustainable use of resources and, while only voluntary, can carry international weight in the form of 'signatory membership' or through governmental interventions. The strongest of these collaborative mechanisms for effecting change to the benefit of small-scale fishers is third-party certification. The goal of achieving sustainable resource use is primarily achieved through an incentive-based approach that aims to reward businesses for compliance with an agreed to set of principles or standards.

The feasibility of certification in the LRFF trade is uncertain for many reasons, including the large volume and number of species traded, the remoteness of fishing grounds, the large number of landing sites and consequent data limitations, the limited institutional capacity to undertake resource assessment and monitoring and to manage the fishery and enforce

compliance, and issues such as corruption and fraudulent reporting. Certification programs can be tailored to accommodate such characteristics, however, and a community-based certification program is one alternative for dealing with the artisanal nature of the LRFF trade (Civic Exchange 2001).

One area of the trade where certification was deemed more feasible was in the mariculture sector. The structure of the LRFF mariculture industry appears to lend itself more easily to a certification framework than does the wild-caught sector.

Collaborative-management models can improve market performance of the LRFF trade by removing differences or practices that constitute barriers, ensure a consistent quality of product, improve the health and safety of industry participants, protect the environment and generate improved returns for all agents in the trade.

### **Market demand and supply through consumer preferences**

In many countries, the environmental awareness of consumers is high, and their collective purchasing power can force industry and stakeholders to change their practices for environmental good. This, however, cannot yet be said for Hong Kong and mainland China, where environmental awareness is as yet at underdeveloped. Research has been carried out previously on consumer attitudes and preferences in relation to LRFF, with major findings including a preference for wild-caught over cultured fish and low awareness of environmental and conservation concerns relating to the LRFF trade (Omnitrak 1997; Chan 2000). It was suggested however, that restaurateurs and importers had some ability to surreptitiously influence consumer preference.

The success of policies aimed at reducing pressure on wild stock populations through maricultured fish, or at removing or reducing LRFF trade inefficiencies and distortions through market mechanism, will depend in a large part on the consumer preferences for cultured over wild-caught fish and the willingness of consumers to pay for 'environmentally sustainable' fish products. The willingness of consumers to accept cultured fish as a substitute for wild-caught species and their demand characteristics toward LRFF are being investigated by other components of this project. Outreach and education programs aimed at increasing awareness of consumers in Hong Kong and mainland China on the environmental impacts of the LRFF trade and encouraging consumption of cultured LRFF will be essential to gaining traction for initiatives that aim to improve market performance.

## **Discussion and conclusions**

An outstanding question with regard to managing LRFF fisheries is whether it is even possible to prosecute a sustained, beneficial fishery (McManus 1997). At question is both whether the enterprise of LRFF fishing can be profitable when kept on a scale consistent with the limited productivity of the resource, and whether the public-management costs needed to keep the fishery within those bounds would be prohibitive. Whether the aim is to develop a sustained, beneficial LRFF fishery, keep the fishery closed, or mitigate its adverse effects, the management response will be costly, requiring administration, enforcement, outreach and training, and monitoring, along with building capacity and, most importantly political will, to establish and enforce policies.

From a policy perspective the purpose of this ACIAR project is to use and apply information collected on demand and supply and market activities to analyse the costs and benefits of changing regulations in the fishery and to identify appropriate policy options for improving the market performance of the LRFF trade through sustainably managing wild-caught stocks, improving price transparency and reducing risk to allow for improved returns to fishers.

This paper is intended as a review of policy options for better managing the LRFF trade. The paper has highlighted the unique characteristics of the trade that make effective fisheries management problematic across the Asia-Pacific. It has further identified a range of policy options, including conventional fisheries management as well as more market and trade-based initiatives, and the merits and limitations of their possible application to the LRFF trade. These barriers to implementing policies that will improve fisheries management and market performance will dictate the extent to which economic, social and environment benefits that these policies can deliver will flow through to countries and actors in trade.

Future work is needed to define approaches to measuring the benefits of a more sustainable and efficient LRFF trade that may come about through the stronger regulation and application of policy options and initiatives presented in this paper.

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