ECONOMIC MODELLING OF THE LIVE REEF FISH TRADE IN ASIA-PACIFIC: DEVELOPING AN APPROACH AND PRELIMINARY ANALYSIS

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ABSTRACT

Reef fish traded alive for table food are high value-to-volume products, with demand centred in luxury markets in Hong Kong and southern mainland China. Approximately twenty countries in the Asia-Pacific region supply these markets. A number of economic, environmental and social issues have arisen from the trade; including the sustainability of wild stocks (it is likely that future demand will need to be met from mariculture), the use of destructive fishing practices in some countries, and the market effects of economic shocks (such as the Asian economic crisis). This paper presents a theoretical framework and preliminary analysis of the trade. Key data challenges and linkages to other fishery models are also outlined.

Keywords: economic modeling, trade, Asia-Pacific

INTRODUCTION

The live reef food fish trade is high value-to-volume, with Hong Kong imports estimated at 15-20,000 tonnes, valued at approximately US$350 million (Muldoon and McGilvray 2004). Sadovy and Vincent (2002) estimate that 60 percent of the international trade goes to Hong Kong, with as much as 50 percent of this being re-exported to southern mainland China. While fish consumption has been a staple dietary component of these countries for centuries, live reef fish are consumed in especially high quantities during special occasions and festivals (for example, in celebration of Chinese New Year, Mothers' Day and to mark the close of business agreements). Approximately twenty Asia-Pacific countries supply these markets, with Thailand, the Philippines, Australia, Malaysia and Indonesia being the dominant suppliers (ACFD 2003). The live reef fish trade is not a traditional market. Supply from south-east Asia and the Indo-west has only established in the 1990s, with Pacific island countries and fishers in some Asian countries fluctuating as suppliers. Demand centres are developing in mainland China and the west coast of the USA, and trade constraints are changing rapidly (e.g., trade barriers in China).[1]

A number of economic, environmental and social issues have arisen as a result of the trade. There are concerns about the sustainability of supply due to economic and biological over-exploitation of coral reefs and the environmentally damaging aspects of some harvesting techniques; including cyanide fishing and targeting of spawning aggregations (Cesar *et al.* 2000). The use of cyanide, is still widely used, albeit illegally, throughout Southeast Asia and in some Indo-west Pacific countries (Johannes and Riepen 1995), and can be fatal to corals and non-target reef fish (Jones and Steven 1997). Over-fishing of live reef species is reported in many Asia-Pacific countries, leading to the dissipation of fishery rents and the erosion of future harvest potential. Several desirable live reef fish species form aggregations to spawn. Fishing of these aggregation sites improves catch rates but can remove much of the breeding stock, with consequent negative effects on reproductive populations. Many live reef fish are long-lived and slow to reach sexual maturation and thus prone to overfishing (Cesar *et al.* 2000). Increasingly, fish are being caught before reaching sexual maturation, and grown-out in cages until they are market size, again eroding the reproductive potential of the fish populations.

Potential benefits from substituting wild-caught fish with cultured species depends on how successfully the mariculture industry relieves its dependence on wild stocks for juveniles and trash fish (Sadovy and Lau 2002). Currently, only Taiwan exports hatchery-reared fingerlings for grow-out (Sadovy 2001). Moreover, the market impacts, and specifically price impacts, of this substitution may have significant effects on fisher income.

Preliminary data analysis indicates that the live reef fish trade has been susceptible to economic shocks such as the Asian economic crisis and, to a lesser extent, Severe Acute Respiratory Syndrome (SARS). The impacts of these shocks are felt throughout the supply chain, from the fisher to the retailer, to different degrees. Moreover, the trade is beset by social disruption, which arises mainly due to disputes over resource access and use, distribution of benefits, and the use of destructive fishing practices. In many cases, while the trade has provided additional income generating opportunities, these benefits have come at a cost to future ecological, economic and social sustainability.

The Australian Centre for International Agricultural Research (ACIAR), in its objectives of pursuing poverty alleviation and sustainable development, would like to encourage sustainable economic development of the live reef fishery. ACIAR funded a project on the Pacific live reef fish trade in the late 1990s, however, the project lost its economic analysis capacity before its completion. A review of the project highlighted the need for further economic analysis of the trade. ACIAR has also funded a number of mariculture projects of live reef fish species in Indonesia and Vietnam. These projects have identified a need for economic analysis to quantify key supply and demand relationships in the market, especially with respect to assessing the potential contribution of mariculture in assisting the long-term sustainability of the trade.

The aim of this paper is to provide a framework for economic analysis of the live reef fish trade. It proceeds as follows. The second section is a discussion on the demand for live reef fish. Background information on demand and preliminary demand analysis to develop hypotheses regarding own-price, cross-price and income elasticities of demand are presented in this section. The third section is a discussion on the supply of live reef fish. It includes presentation of background information to supply, preliminary supply analysis to develop hypotheses on the price elasticities of supply, and discussion on the interaction between captured and maricultured product. The fourth section is a discussion on how the demand and supply analyses might be integrated to form a multistage model of the trade, and how the multistage model might be used to analyse the impacts of shifts in demand and supply arising from different future scenarios; such as technology change, income growth and changes in fisheries regulatory or other government policy. The paper ends with a conclusion.

THE DEMAND FOR LIVE REEF FISH

Background on the demand for live reef fish

Live fish have long been traded throughout Southeast Asia as a luxury food item. Fish captured on coral reefs entered this trade in the 1970s and, because of their superior taste or texture, have become the most sought after species. Demand fluctuates through time, coinciding closely with events on the Chinese lunar calendar, and is observed to peak on traditional Chinese festival periods such as Chinese New Year, Mother's Day, Mid-Autumn and Full Moon Celebrations. These festive periods often correspond with higher prices paid to fishers in source countries.

Quantities of live fish traded regionally are difficult to determine. Actual records of annual imports of live fish into Hong Kong are derived from data collected by the Census and Statistics Department (CSD) and the Agriculture, Fisheries and Conservation Department (AFCD). The reliability of these estimates is hindered by likely under-recording of imports (as a result of there being no requirement for Hong Kong

registered live transport vessels to declare their imports) and the re-export of live fish into southern mainland China. Live transport vessels generally carry in live product from South-east Asia and the Indo-west Pacific. The AFCD estimates of live marine fish entering Hong Kong by sea are thought to capture only about 50 percent of all shipments and do not distinguish country of origin. It was not until improvements to reporting systems in the late 1990's that imports of live reef fish by air were able to be disaggregated by key species and country of origin.

Accounting for under-reporting, imports of live reef fish into Hong Kong in the mid 1990s were estimated to be 30,000–35,000 tonnes annually (Lau & Parry-Jones, 1999). Sadovy and Vincent (2002) estimate that up to 50 percent of Hong Kong imports are re-exported to southern mainland China, where direct import tariffs are significantly higher than in Hong Kong. Given estimates that Hong Kong receives approximately 60 percent of global imports, the global trade in live reef fish may have exceeded 50,000 tonnes annually. In the immediate wake of the Asian economic crisis, declared imports of live fish into Hong Kong declined by almost one-third and have since failed to recover from these levels. Imports entering Hong Kong in 2002, were estimated at 18,000 tonnes, representing a total global trade of around 30,000 tonnes (Sadovy *et al.*, 2004).

The market for live reef fish includes a wide variety of low, medium and high value fish species (Table 1). Until the late 1990's the market was dominated by low-value species such as snooks and basses, wrasses and other marine fish. The preferred family of fish species are the grouper (Serranidae); made up of low-value (i.e. malabar, greasy and green grouper), medium (giant, tiger and flowery grouper) and high-value (leopard coral trout and highfin grouper) species. One other species, the humphead (napoleon) wrasse, remains one of the highest priced and most sought after fish in the trade. Retail prices for live fish during 2002 ranged from AUD$8 to AUD$100 per kilogram (kg), depending on species, taste, texture, availability, and time of year. The preferred size of fish (family-size) for consumption is 600 –1000 grams. Both wholesalers and exporters in source countries and importers in Hong Kong pay higher prices for plate-size fish, while over and undersize fish sell at lower prices.

Table 1: Estimates of quantity, price and value of live marine fish imported into Hong Kong by Hong Kong flagged vessels in 2002.[a]

Species	Quantity (tonnes)	Wholesale price (AUD$/kg)	Value (millions AUD$)
Other marine fish	4,669	8.52	39.8
Leopard coral trout	2,450	53.34	130.7
Other groupers	1,697	40.01	68.0
Green grouper	1,464	16.13	23.6
Snooks & basses	1,217	8.52	10.4
Tiger grouper	392	38.59	15.1
Flowery grouper	329	34.31	11.3
Spotted coral trout	318	34.53	11.0
Mangrove snapper	239	15.19	3.6
Wrasses & parrotfish	103	8.52	0.9
Humphead wrasse	46	91.06	4.2
Giant grouper	29	37.70	1.1
High-finned grouper	26	96.65	2.6

Source: Hong Kong Trade Statistics from Census and Statistics Department, and the International Marine Alliance.

[a] Non-Hong Kong flagged vessels are estimated to capture approximately 50 percent of imports to Hong Kong.

Of the species presented in Table 1, only green grouper, tiger grouper and mangrove snapper are cultured. With the exception of green grouper in Taiwan, culture is based on collection and grow-out of wild-caught fingerlings and juveniles. The Nature Conservancy (1997) reports results of blind taste tests to determine the substitutability of live maricultured and wild-caught malabar grouper (a low value species). They found that the taste of live maricultured malabar grouper was of similar quality, and sometimes preferred to, wild-caught malabar grouper. Preferred quality attributes included a smooth texture for skin and flesh, a white coloured flesh, relatively small in size 700-800 grams, and a fatty layer under the skin. The taste tests also included comparison of maricultured and wild-caught malabar grouper with the leopard coral trout, with the latter found to be consistently superior. This report provides evidence that some maricultured species are substitutes to wild-caught species, although no econometric analysis has been done to estimate cross-price elasticities of demand.

Demand analysis

The simplest way of conducting demand analysis on the live reef fish trade may be to estimate the standard Marshallian demand function, expressing the quantity of a species demanded as a function of prices, income and seasonal factors. However, being a single equation model, this methodology may not be theoretically consistent as changes in the price of goods omitted from the specification may cause changes in demand for the commodity in question through changes in expenditure. To estimate functions that are consistent with consumer theory, the concept of weak separability is used to separate a group of goods from the rest of the consumer's bundle. Weak separability assumes that the consumer partitions total consumption into groups of goods, so that preferences within groups can be described independently of the other groups. The demand functions for the goods inside the group are then specified in a system of demand functions. There are a number of demand systems specified in the literature, of which the most commonly used is the Almost Ideal Demand System (AIDS) of Deaton and Muellbauer (1980).

One advantage of using the AIDS functional form is that it is consistent with the methodology used by the WorldFish Center in constructing their Asian Fish Model - a partial equilibrium model of fish consumption in nine Asian countries that includes approximately ten different fish groups (the latter depending on the country) (Dey 2000a). Live reef fish is not explicitly included as one of these ten groups. In time, a demand model of the live reef fish trade could be incorporated into the Asian Fish Model to provide more detailed analysis of the trade in the region. However, while all live reef fish supplied to Hong Kong is sold, it may be sold in different forms (dead (frozen or fresh) or alive). Hence the system is not closed. This may pose problems with estimating an AIDS model, and may force the use of a single demand function.

The following subsections review the literature and propose hypotheses regarding own-price, cross-price and income elasticities of demand that can be derived from empirical analysis.

Price elasticity of demand

A number of general trends may be elicited from existing demand models for fish, although comparisons must be made with caution as model specifications used differ across studies. First, demand in most markets for seafood seems to be price elastic (Asche and Bjorndal 1999). There are a few exceptions; for example, demand for some canned seafood in aggregate such as canned tuna (e.g. Wallstrom and Wessells (1995)). Second, there is a tendency for more valuable seafood to be exhibit more elastic demand. Third, existing demand analysis of fisheries show a tendency for demand closer to the consumer (e.g. retail demand) to be less elastic than demand closer to the producer (e.g. ex-vessel demand). A

fourth, and related, finding from existing demand analysis is that price elasticities decrease with increases in supply, as one would expect with a movement down the demand curve. As some live reef fish are high value-to-volume species, demand for these fish is also expected to be price elastic. Furthermore, the relatively high-priced live reef fish species are expected to have greater elasticities than the relatively low-priced species. For live reef species where production is increasing rapidly (e.g., leopard coral trout), the price elasticity of demand is hypothesised to be decreasing.

We identify two special demand features of the live reef fish trade. First, increases in demand during celebration periods leads to price spikes, suggesting consumers are willing to pay a considerable premium to ensure purchase during such periods. The price elasticity of demand may be highly inelastic during such periods. The second is consumers' willingness to pay higher prices for scarce fish species (e.g., humphead wrasse). The effect of these 'trophy' prices is likely to encourage greater levels of effort, leading to over-fishing of the resource in the absence of regulation.

Cross-price elasticities of demand

Demand studies of other fisheries provide some evidence that similar species and product forms tend to be the closest substitutes. Salvanes and DeVoretz (1997) found that the degree of substitution between seafood and meat is substantially less than between seafood products. Asche *et al.* (2001) and Jaffry *et al.* (2000) found little substitution between farmed and wild-caught products when comparing different species, but Asche *et al.* found some substitution when comparing similar species. From these studies, hypotheses may be developed for different live reef fish species; namely, that live reef species and other species (such as non-live species or other meats) are not substitutes; that different wild-caught species with dissimilar quality attributes, and wild-caught and maricultured species, are weak substitutes; and that different wild-caught species with similar quality attributes will be close substitutes. To test these hypotheses, cross-price elasticities should be measured through empirical demand analysis.

Income elasticities of demand

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

The Hong Kong economy has grown very slowly over the last few years due to a slow-down in the global economy, the Asian economic crisis and the economic effects of SARS (EIU 2003a). This slow economic growth (2.3 percent in 2002) has led to poor levels of growth in income, and hence disposable income, that may be spent on reef fish consumption. The prospects for growth in the Hong Kong economy is promising for the medium term, with the Economics Intelligence Unit forecasting 5.4 percent growth in 2003-2004 (EIU 2003a). Moreover, mainland China's economy has been growing strongly over the last few years and this looks to continue in the medium term, with GDP growth of 8 percent forecast for 2003-04 (EIU (2003b). This income growth in Hong Kong, and especially mainland China, is likely to lead to increased demand for all species of live reef fish.

THE SUPPLY OF LIVE REEF FISH

Background on the supply of live reef fish

The traditional sources of live reef fish are the inshore reefs surrounding Hong Kong and those in the South China Sea. As fish stocks on those reefs began to show signs of depletion, Hong Kong fishers began to move farther afield. Beginning with the Philippines in about 1975, there has been a gradual expansion of the live fish trade into other South-east Asian, and the Indo-west and south Pacific countries.

Now, the supply of live reef fish originates from approximately 20 countries. For most source countries, data collected on live reef fish exports are not disaggregated to a species level. Moreover, perhaps with the exception of Australia, species exports are generally mis-reported and under-reported, and include non-live reef fish. Hence, caution must be used when analysing this data. Table 2 provides estimates of quantity, price and value of live marine fish supplied from the 10 largest suppliers by volume. The five largest suppliers make up over 90 percent of the trade; China (30 percent), Thailand (27 percent), Philippines (13 percent), Australia (12 percent) and Indonesia (11 percent). Thailand's exports are dominated by low-price species such as green grouper, mangrove snapper and flowery grouper, while for the Philippines and Australia the high-value leopard coral trout are the main export species. Hence, despite a lower volume of total exports from Australia and the Philippines, the value of their live fish exports is higher than Thailand. This is especially true for Australia, where the leopard coral trout comprises approximately 90 percent of all exports. Thailand and Taiwan export large quantities of farmed grouper (both hatchery produced and wild-caught grow-out fish), mainly orange-spotted grouper, while China is the dominant supplier of low-value marine fish, snooks and basses.

Table 2: Estimates of quantity, price and value of live marine fish supplied from the 10 largest (by volume) suppliers.

Source Country	Quantity (tonnes) [a]	Value (thousand US$) [b]	Value (thousand AUD$) [c]
Mainland China	3,307	40,448	74,339
Thailand	3,023	46,969	86,325
Philippines	1,426	54,819	100,751
Australia	1,402	66,198	121,664
Indonesia	1,206	37,517	68,953
Malaysia	486	16,948	31,149
Vietnam	132	3,893	7,154
Taiwan	99	2,038	3,745
Japan	78	9556	1,757
Maldives R	59	2,445	4,493
Marshall Islands	60	2,302	4,231
Cambodia	43	956	1,757
TOTAL	**11,321**	**275,488**	**506,319**

[a] Quantities shown do not include imports recorded by the AFCD because firstly, data on species are not available by country of origin and secondly volumes recorded by the AFCD are based on voluntary provision of data by Hong-Kong registered vessels. It is observed that AFCD volumes capture approximately only 50 percent of all imports by sea (Muldoon and McGilvray, 2004)

[b] Values shown do not include value of AFCD recorded imports because data are not available by species or country of origin. The total value of all species recorded by the AFCD is US$ 63 million.

[c] Australian dollar values have been estimated using the average USD:AUD exchange rate for 2002 of 0.5441. The Australian dollar value of AFCD imports is estimated at A$ 116 million.

The supply chain of live reef fish trade is complex, with up to five links in the chain from fisher to retailer. The number of suppliers in the supply chain differs between countries. In general, local fishers sell their catch to local buyers and exporters at or near the fishing grounds. The local buyers (middlemen) will collect fish until sufficient numbers have been accumulated for export. Fish that are too small for market may be kept in floating cages and fed (called grow-out aquaculture) until they are large enough for export. Once they reach the export stage, the fish are transhipped to Hong Kong by air or sea. In the absence of available air links, as is the case in the Pacific, fish are transported to markets on live fish carrier vessels. Once they arrive in Hong Kong, importers transport the shipments to the central wholesale fish market, or store the fish offshore in cages. The time between importing the species and selling it to the wholesaler may be between a few days and a number of months, depending on the mode of transport (ship or air). Distributors then purchase the live fish and sell them to retailers in Hong Kong and southern mainland China. The Pacific Live Reef Fish Trade Initiative (2002) estimate that 10 percent of total returns go to community fishers, 35 percent to local buyers and exporters, 5 percent to Hong Kong importers and wholesalers, and 50 percent to retailers (although the retailers may value-add to the fish through the cooking process). Although the importers are receiving a small proportion of returns, they are also bearing a large proportion of the risk (F. McGilvray[2], personal communication, September 2003).

Sadovy and Vincent (2002) estimate that fish mortality through the marketing chain can be as high as 50 percent. Mortality rates are often much lower when fish are freighted by air with mortality rates reported to average less than 5 percent. Most fish deaths occur during the holding phase in the source country and are attributed to the use of cyanide, overstocking of cages, poor cage condition and feeding practices and disease. Mortality, particularly with sea transportation, is usually factored into the importers buying price and is dictated by the condition of the fish, distance to market, and the supplier's history. Another factor dictating buying price is weight lost by the fish during transit, which can be as much as 15 percent (P. Chan[3], personal communication, September 2003). However, the market clears once the fish reach Hong Kong as wholesalers do not want to risk holding stock for significant periods (F. McGilvray, personal communication, September 2003).

Approximately 15 to 40 percent of the live fish trade are maricultured (this variation is due to uncertainty in any given year). China, Thailand, Taiwan, Indonesia and Vietnam are the main exporters of farmed grouper, with the majority of these being grow-out of fingerlings and juveniles to market size. Concerns about overfishing of wild fish populations have seen an increased focus on mariculture to supply key grouper species to the trade. For example, the proportion of cultured green groupers increasing to 95 percent of all imports (P. Chan, personal communication, September 2003). Historically, there was a considerable difference between wholesale and retail prices for cultured and wild-caught individuals, mainly due to consumer perceptions of taste and flesh quality. However, there is little evidence of these price differences now.

Supply analysis

Empirical estimation of elasticities of supply in some source countries should be possible from the market data – at least as a preliminary analysis – as many changes in supply have been driven by demand-side shifts, such as the Asian Economic Crisis and SARS. Using a translog revenue function to estimate live reef fish supply will ensure consistency with the methodology used by the WorldFish Center in constructing their Asian Fish Model (Dey 2000b). This would allow the option of incorporating a live reef fish supply model into the Asian Fish Model in a similar fashion to the demand modelling mentioned earlier.

However, such elasticities may not be good indicators of future supply due to over-fishing or the introduction of output quotas that restrict catch levels (e.g. In 2003, the Queensland Fisheries Services

implemented a Total Allowable Catch and individual quotas for the reef-line fishery which supplies live fish from the Great Barrier Reef). Therefore, detailed analysis of the supply of live reef fish will require bioeconomic modelling.

Price elasticities of supply

Supply elasticities for seafood reported in the literature are generally low, and often very low (Squires 1987a,b; Kirkley and Strand 1988; Squires and Kirkley 1991; Salvanes and Steen 1994; Keefe and Jolly 2001; Salvanes and Squires 1995; and Pascoe and Mardle 1999). Supply is not terribly responsive to price due to the limited stocks of fishery resources, restricting how responsive fishers can be to market signals. The supply of wild-caught fish is particularly complex due to the backward-bending supply curve, that is a consequence of the fisheries biological growth curve (Anderson 1985). On the backward-bending part of their supply curve, an increase in price will actually lead to a decrease in equilibrium supply due to a lack of available biological stock. This perverse supply effect of fishing, whereby increased effort or improved catchability from improved technology in the short term, will increase costs in the long term as stocks are depleted even further. Moreover, as many of the world's fish stocks are reported to be fully or over-exploited (FAO 2002), it is likely that the market equilibrium of these fish stocks is on the backward-bending part of the curve.

The economics of maricultured fish may be similar to that of wild-caught fish if mariculture farms are dependent on wild stocks for fingerings or trash food. The backward-bending supply curve does not exist for farms that uses hatchery-reared fingerling for growout. However, there may be a lag between the change in price and changes in quantity supplied, due to the time needed to restock and culture the fish.

From this we may hypothesise that the price elasticity of supply of live reef fish is inelastic (especially as most live reef fishers are operating at or just above subsistence), and that supply from countries where the trade has been occurring for longer periods without regulation may be more inelastic than the supply from regulated fisheries or fisheries where biological stocks are still high. A thorough analysis of these fisheries is needed to estimate which of the live reef fisheries are on the backward-bending part of the supply curve. Available evidence suggests that over-fishing of live reef fish stocks is occurring in unregulated fisheries such as the Philippines, Indonesia, Malaysia and Vietnam (Bentley 1999; IMA 2001, Graham *et al.*, 2003).

Interactions between mariculture and capture fisheries

The interaction between maricultured and wild-caught fish products depends on the degree of substitutability between the two products and the level of competition for ocean resources (Anderson 1985; Ye and Beddington 1996). Where the two products are competing for ocean product (i.e., where mariculture farms source fingerlings and trash food from wild-stocks), the market interaction will be greatly reduced. Where captured and mariculture fish supply are not competing for ocean product, and where the new maricultured product is the same as the captured product, the new market equilibrium will have a lower market price, increased total supply, reduced fishing effort and increased wild fish stock levels. If the cost of mariculture production is reduced (e.g., through technological improvement) and the cost of fishing effort is held constant, higher profitability will attract new investment, increasing supply and putting downward pressure on fish price. Lower prices will cause fishing effort in capture fisheries to decrease allowing stock levels to increase. Where fish species are substitutes, they have separate prices and demands, but demand can switch to each other depending on prices. Similar market interactions will be experienced, but to a lesser extent. Hence, when species are not in competition for wild-stocks for fingerlings or trash food, the farming of that species or a substitute can relieve pressure on the capture fishery.

Such market impacts may be especially beneficial where regulatory frameworks to reduce fishing effort is weak or absent. This is the case for many live reef fisheries. However, before market interactions can work to boost biological stocks of reef fish, the current reliance of the mariculture industry on wild stocks for fingerlings and trash food must be reduced. These market interactions between wild-caught and maricultured fish product can be determined using an integration of demand and supply analysis, as will be described in what follows.

INTEGRATING SUPPLY AND DEMAND ANALYSIS

Demand and supply analyses can be combined to form a multistage partial equilibrium model. This model can be used to estimate the market implications of shifts in supply and demand. The following is a simplified model developed from the methodology of Freebairn *et al.* (1982) and Haynes *et al.* (1986).

We assume a perfectly elastic supply of marketing goods and service, linear supply and demand curves, a constant per unit margin between fisher and retail prices and competitive price behaviour. Though not documented here, these assumptions can be relaxed to form more complicated models (see Freebairn *et al.* (1982)). The simplified model is shown in Figure 1. Retail or final consumer demand is D_r, the constant unit cost of providing marketing services is M, and the derived demand curve for the fisher is $D_f = D_r - M$. The fisher supply curve is given by S_f. Using these assumptions, the equilibrium quantity is Q, the retail price is P_r and fisher price is P_f.

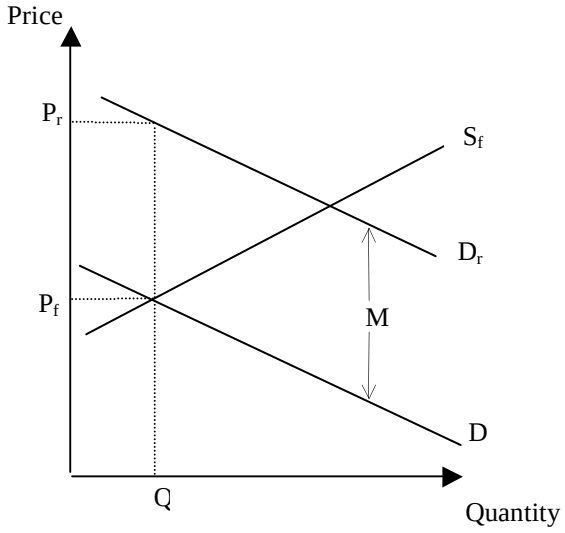

Figure 1: Integration of demand and supply analyses

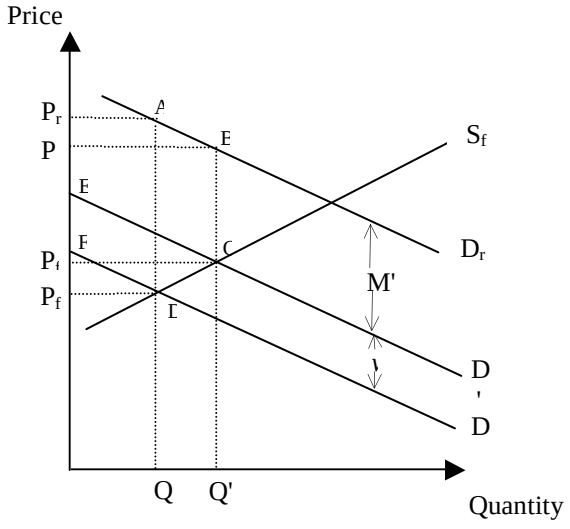

Figure 2: The market effects of a technology change reducing marketing costs

To illustrate how the simple model could be used to analyse the market implications of a shift in supply or demand, consider the impacts of a technological change in the marketing stage that decreases marketing costs by w (e.g., a decrease in costs of providing storage, transport or distribution) (Figure 2). The retail to fish margin decreases to $M' = M - w$, leading to an upward shift of the fisher demand curve to $D_f' = D_r - M'$. Equilibrium quantity increases from Q to Q', equilibrium fisher price increases from P_f to P_f' and equilibrium retail price falls from P_r to P_r'. Due to the fall in retail price, consumer surplus increases by $P_r'P_rAB$, the quasi-rent to fixed fisher resources increases by $P_f P_f'CD$, and the aggregate gain is FECD.

The above is an example of how an integrated demand and supply model can be used to analyse the market implications of shifts in demand and supply. These shifts may arise due to forecast changes in future consumption and production, technology change, income growth, changes in fisheries regulatory policy and changes in other government policy. This multistage framework may also be used to generate important information about the beneficiaries of shifts in supply and demand. For example, Freebairn *et al.* (1982) found that research that reduces production costs at one stage of the production chain provides benefits to producers at all stages, as well as consumers. They also found that agricultural producers may receive greater benefits from off-farm-oriented research than from farm-oriented research. Applying this analysis to the live reef fish trade may have important implications on the distribution of research benefits for individual fishers from developing countries, assisting ACIAR in its objectives of pursuing poverty alleviation and sustainable development.

CONCLUSIONS

A number of economic, social and environmental impacts have arisen from the relatively recent development of the live reef food fish trade. This paper presents some background information on these impacts, and proposes a theoretical framework for market analysis of the trade. The framework involves empirical supply and demand analysis of the trade, and the integration of these analyses to form a multistage supply and demand model. This model can be used to investigate the market impacts of changes in supply and demand caused by changes in variables such as future production and consumption, technology, income growth, and fishery and other government policy. These impacts can be traced through the various stages of the marketing chain so that the beneficiaries can be identified. The framework also recommends use of bioeconomic modelling of key supply fisheries to elicit short and long-term price elasticities of supply, and to provide more detailed policy analysis.

The biggest constraint on this framework is likely to be limitations in data availability and quality. Sufficient data is available from Hong Kong import data to conduct initial empirical demand and supply analyses. There are concerns about data deficiencies, although these deficiencies are likely to be a consistent through time, so that empirical analysis may still provide meaningful results. Long-term price elasticities of supply are likely to be difficult to measure due to a lack of data on the biological status of supplying fisheries. The Australian reef-line fishery that supplies live fish from the Great Barrier Reef is one of the only live reef fisheries that is strongly regulated and for which significant biological and economic information exists. This may provide an important case study for analysing different management policies, and could be used to provide information to Australian policy-makers, and their Asia-Pacific counterparts.

The ACIAR-funded project based on this methodology (due to start in August 2004), is expected to produce short and long-term demand and supply elasticities (accounting for expected income and population growth and biological stock constraints). This will be disseminated to reef fishers in Asia-Pacific, most of whom have little market information on the trade, and fishery managers. Spreadsheet models will be developed for at least two southeast Asian and two Pacific countries that includes benefit cost analysis, and key risk components in the marketing chain. This will provide further information to fishers and fishery managers, and is likely to be especially useful in the Pacific, where information is scarce, risk of mortality is high and net benefits may be marginal.

Information on product attributes preferred by Hong Kong consumers will be disseminated to ACIAR mariculture projects, to be used to develop mariculture production technologies. The degree to which wild-caught and maricultured products are substitutable will be estimated and provided to other ACIAR projects. Additionally, information on policies for improving market performance will be provided to key decision-makers of capture and mariculture fisheries. These policies may include methods for enforcing bans on destructive fishing practices and institutions for restricting fishing effort. By encouraging fishing

harvest to be restricted to the maximum economic yield, dissipation of fishery rents (caused by the harvesting of immature fish which leads to the erosion of harvest potential) will be reduced. This is likely to lead to increased returns to reef fishers who are often operating at, or just above, subsistence levels. Economic analysis of the trade that provides market forecasts and trends to fishers, and informs fishery managers about the impacts of different regulatory policy, is an important step to promoting the sustainable economic development of the trade.

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ENDNOTES

[1] In this paper, we refer only to live reef fish traded for table food and not aquarium display. Estimates of the value of retail aquarium trade in the late 1990s range between US$90 and US$400 million (Sadovy and Vincent 2002).

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