While Stocks Last: The Live Reef Food Fish Trade

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Cover: Some of the species used in the live reef food fish trade. Fish illustrations by Les Hata. Copyright; Secretariat of the Pacific Community.

FOREWORD

This book is the result of the work by nine independent scientists who agreed to contribute their time to write on specific topics within their individual expertise on live reef food fish (LRFF) trade issues. At a workshop in Suva, the Fiji Islands in September 2002, it was agreed that the alarming data and information published recently about the perilous state of most of the world's fish populations more than justified the need to document the special concerns about the LRFF trade in a stand-alone publication. This book does not in any way claim to cover all the different aspects of the LRFF trade, but should be read as offering a thorough analysis of the situation in 2003.

The workshop was the last in a series of activities funded by the Asian Development Bank under a regional technical assistance project on Strengthening the Live Reef Fish Trade Management in the Pacific Developing Member Countries, which was jointly implemented by the Secretariat of the Pacific Community and the International Marinelife Alliance. Community consultations, assessments of fish abundance, and appropriate awareness materials were produced to assist the countries and the various stakeholders with the challenging management issues facing the expanding LRFF trade.

The picture that emerges from this book is extremely worrying: the LRFF trade has caused degradation of the resources on which the trade depends, and hence has to move farther and farther from the main market centers in order to continue to supply them.

The LRFF trade not only threatens to deprive coastal populations in remote islands (in South and Southeast Asia and the Pacific) of one of their few livelihoods, but it also threatens the resilience of the reef ecosystems by removing key predator species. Especially in the Pacific region, many reef ecosystems are already under strain from the increased frequency of the El Niño phenomenon, which has resulted in the warming of surface waters and bleaching and death of corals. These factors, when added to nonsustainable fishing practices and the ever-growing quest for other high-value species, such as sea cucumber, trochus, and other

shellfish, all add up to the increased probability that reef ecosystems will lose their inherent robustness and face unpredictable changes.

It is clear that management plans and awareness materials for the LRFF trade alone, such as those developed under this technical assistance project, are not sufficient to secure the livelihood of future generations or the health of these important ecosystems. Extreme caution needs to be applied if we are to safeguard these resources for the future.

Jeremy Hovland
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Pacific Department

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We are indebted to the Secretariat of the Pacific Community for the fish illustrations by Les Hata; to CSIRO Marine Research, Dr. John E. Randall, and Patrick Lau for some photographs; and Asia-Pacific Economic Cooperation and the Society for the Conservation of Reef Fish Aggregations for photographs emanating from projects of these organizations.

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The book was edited by Jay Maclean and Yvonne Sadovy.

ABBREVIATIONS

AFCD	Agriculture, Fisheries and Conservation Department (Hong Kong, China); formerly Agriculture and Fisheries Department
APEC	Asia-Pacific Economic Cooperation
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
CPI	consumer price index
CSD	Census and Statistics Department (Hong Kong, China)
FAO	Food and Agriculture Organization of the United Nations
IMA	International Marinelife Alliance
IUCN	World Conservation Union
LRFF	live reef food fish
PRC	People's Republic of China
SARS	sudden acute respiratory syndrome
SCRFA	Society for the Conservation of Reef Fish Aggregations
SPC	Secretariat of the Pacific Community

NOTE

$ means US$ throughout, unless otherwise specified.

CONTENTS

SUMMARY

Background

Live fish have long been traded around Southeast Asia as a luxury food item. Fish captured on coral reefs entered this trade only in recent years but, because of their superior taste or texture, have become the most valued fish in the trade. The majority of live reef food fish (LRFF) are imported into Hong Kong, China either for local consumption or for transshipment to mainland People's Republic of China (PRC).

The LRFF trade presently includes a wide variety of fish, but is dominated by several kinds of groupers. Retail prices for LRFF range from US$5 to $180 per kilogram (kg), depending on species, taste, texture, availability, and time of year—prices rise during festive periods. Preferred size of fish (family-size) for consumption is 600 grams–1 kg. The trade is not well monitored, but is likely to involve at present about 18,000 tonnes (t) of fish per year entering Hong Kong, China. The total regional trade may be around 30,000 t per year, with Hong Kong, China estimated to account for about 60% of the trade.

The trade is complex, with many links in the chain from fisher to retailer. Fish enter the trade either as wild-caught fish that are held briefly before export, about 50–70% of the total trade (15–21,000 t); undersize fish that are grown in cages or ponds until they reach market size, 15–40% of the trade (about 5,000–12,000 t); or reared from egg to market size in controlled conditions in full-cycle (i.e. hatchery-based) aquaculture, 10–15% (3,000–5,000 t). Transport of LRFF is by sea or air, depending mainly on the location of the fishery or holding facilities and available air links.

The fishing grounds shifted rapidly in response to increasing demand in the 1990s. Reefs near Hong Kong, China were quickly depleted and sources of capture now extend well into both the Pacific and Indian oceans, broadly the Indo-Pacific region. With few exceptions, the fishery for market-sized fish tends to remain in one area for a short period, often no more than a few years until the target fish become hard to find, then moves

on; thus, it is characterized, from the point of view of the countries concerned, as a sequence of "boom-and-bust" operations. The nomadic fishery may move on to different fishing grounds within a country, as in Southeast Asia, or to different countries, as in the western Pacific.

The major issues facing the trade are

- overfishing and consequent depletion of resources that are in many cases used in other subsistence or commercial fisheries;
- destruction of coral and mortality of nontarget fish when using cyanide solution in some places;
- fishing the spawning aggregations of some target fish, causing depletion of reproductive fish;
- the contribution of reef fish aquaculture, which is still largely dependent on grow-out of wild-caught fish, to depletion of the target fish stocks —and the extensive use of wild fish as fish feed;
- the wastage of nontarget fish—many are killed during fishing operations but not eaten, while many fish that could be used as food in local communities are caught to feed LRFF during grow-out—and because of deaths of target fish before reaching the market;
- social issues resulting mostly from conflicts and corruption regarding prices and access to fish, and from injuries and deaths from diving; and
- the inclusion of threathened species in the trade.

Economics and Trade

Actual quantities of fish in the trade are difficult to determine. For most source countries, LRFF exports are not disaggregated at a species level, and species are misreported and underreported. Even in the major trading center, Hong Kong, China, the full extent of the trade is unknown. Improvements to the harmonized code system there in 1997 and 1999 enabled identification of major imports of LRFF to species or species group level. However, imports by Hong Kong, China-licensed vessels do not have to declare their imported fish, although some such vessel

operators voluntarily supply import figures to the Government. Also, LRFF trade between Hong Kong, China and mainland PRC is not documented.

Government figures show an overall decline in the total volume of imports of LRFF into Hong Kong, China from about 22,000 t in 1998 to about 13,000 t in 2002. During this period, there were marked changes in the composition of imported LRFF, such as the rising numbers of Australian coralgroupers, declining proportions of some species from other countries, and a doubling of imports of brown marbled groupers.

Based on government data on imports and retail prices, the gross retail value of the trade in Hong Kong, China during 1999–2002 was around $350 million per year. Corrected for unreported fish, the total retail value in 2002 of the trade there was around $486 million and for the region as a whole, about $810 million.

The main exporting countries of LRFF are Indonesia, Philippines, Australia, PRC, Malaysia, Thailand, Viet Nam, and Taipei,China. Other countries involved are Fiji Islands, Maldives, Marshall Islands, Papua New Guinea (PNG), Seychelles, Singapore, and Solomon Islands. The higher-priced fish come mainly from Indonesia, Malaysia, Philippines, and Australia.

Beach prices, those paid to the fisher or fishing company that caught the LRFF, are generally in the range of 2–4 times the price paid for the same fish when dead.

There is a mark-up of 100–200% on wholesale prices in Hong Kong, China, because of the high rental costs, the restaurant's reputation and location, and the desirability of the LRFF purchased. Both wholesale and retail prices are on average higher in mainland PRC than in Hong Kong, China. There is a considerable difference between wholesale and retail prices for cultured and wild-caught individuals for some species, often attributed to consumer perception that cultured fish do not have the same taste and flesh qualities as a wild-caught fish of the same species.

Capital costs of the trade vary enormously across the exporting countries, from floating cages to vessels, to land-based holding facilities. Similarly, operating costs vary, primarily according to the mode of holding fish and their transport, mainly to Hong Kong, China. The increasing use of air transport, where available, has probably lowered investment risks, particularly to importers/major traders.

Macroeconomic issues affect the trade in both exporting and importing countries. For example, the decrease in the Hong Kong, China consumer price index from end-1997 to end-2002 was accompanied by falls in wholesale and retail prices of LRFF. Of growing concern is the LRFF market expansion associated with increasing incomes in mainland PRC, which is placing increasing pressure on supplies of wild-caught stocks. Source countries have experienced decreasing prices for LRFF in recent years but the impact of these price declines has been mitigated by favorable exchange rate fluctuations, as the US dollar strengthened against other currencies.

At present, value adding—the price increment paid for live fish above the price of similar dead fish—remains one of the key attractions of the LRFF trade in most source countries. While complex business relationships tend to obscure the real distribution of value among market participants, returns from LRFF fisheries evidently remain profitable for some in many countries.

Fish Resources

The most desired fish in the LRFF trade, the groupers, are relatively uncommon and long-lived, and mature late in life. Thus, reefs can be depleted quickly. Some of these groupers form spawning aggregations, which are sometimes fished heavily with consequent negative effect on the reproductive component of the population. At other times, the capture of a large proportion of juvenile fish or young adults—most groupers are females at this time, changing sex as they grow larger—also potentially reduces the reproductive population.

Total regional grouper production from all sources, live and dead, was estimated to be about 184,000 t in 2001, with the following components. Total LRFF wild-caught market-size grouper production from reefs in the Indo-Pacific region was about 21,000 t, while production from grow-out culture of wild-caught groupers was estimated at 32,000 t. Both figures include an average mortality estimate of 50% between capture (or farm) and market. The regional grouper fisheries catch (from FAO data), which is assumed to overlap little with that of the LRFF fisheries,

and therefore represents the dead fish component, was 131,000 t in 2001. Thus, live fish represent almost 30% of total grouper production in the region.

These data represent an average total, annual grouper yield of about 0.6 t per km^2 in 2001 across the total Indo-Pacific reef area of some 284,300 square kilometers (km^2). Assuming that about 80% are LRFF species, then regional yield of LRFF species was close to 0.5 t per km^2.

Past surveys and studies in various parts of the region indicate that total attainable fish yields from reefs in moderate condition may average some 5 t per km^2 per year, of which groupers make about 10%, or about 0.5 t per km^2, and LRFF species, thus, about 0.4 t per km^2. This value is close to the present yield.

The trend of the FAO production data suggests that the overall grouper fishery has not yet reached maximum catch level and that yield, therefore, can still rise. However, possibly much of the increased catch in recent years is from expansion of fishing areas rather than yield increases. Further, for live fish, at least, most yield comes from a relatively small portion of the region. There is every indication that wherever an LRFF fishery occurs it is usually associated with localized heavy depletions—and demand is expected to grow.

Ultimately, the impact of excessive extraction of live fish on local subsistence and commercial fisheries for the same target species could result in fishing down the food chain with unknown long-term ecosystem effects through changes in interactions between organisms. A new equilibrium could arise in the absence of some of the top predators (groupers), possibly precluding the reestablishment of groupers and other affected species, and threatening vulnerable species like humphead wrasse.

Social Issues

The nature of the LRFF trade in the region—often boom-and-bust within the countries concerned—has meant that most of the initial expectations of governments and fishing communities have gone unrealized. The trade has provided some communities with the opportunity to earn, temporarily at least, additional income from their fish resources in areas where very few

income-generating opportunities exist. Also, some communities have benefited by receiving funds for community needs. However, these benefits have often come at considerable cost, ecologically, economically, and socially. There has also been significant health impact from diving-related accidents, because of inadequate training of divers and poor equipment.

There are very few places where social disputes and disruption have not occurred as a result of the LRFF trade. Commonly, disputes erupt between the operators and fishing communities over issues to do with prices, destructive methods, and unfulfilled promises. Another social impact has been the development or exacerbation of disputes between fishers and even villages over ownership and use rights to areas and resources, and over distribution of benefits such as the payments of royalties. One of the most significant legacies of the LRFF trade has been corruption and coercion. There are also tensions within communities between fishers who use cyanide and those strongly opposed to it. The LRFF trade has been responsible for the introduction of sodium cyanide as a fishing "method" into areas previously naïve to this method.

Another legacy of the LRFF trade, once it moves on, is degraded habitat, reduced reef resources, and reduced reproductive potential from the use of fishing methods that destroy habitat, the reduction and possible elimination of reef fish spawning aggregations, and the removal of juveniles (and hence reproductive potential) for grow-out. Many of the target fish are important for both subsistence and local commercial fisheries, and the added pressure from the LRFF trade, which may result in extreme overfishing, can have a negative effect on the resources long after live fish businesses have moved on. In addition to the loss of these fish resources for local use, there is also a loss of potential alternative income-generating opportunities, such as scuba diving and other ecotourism-related activities, while species diversity is also threatened.

Fisheries Management and Trade Controls

In most countries, LRFF fisheries have arisen alongside existing subsistence fisheries and, thus, cannot be viewed in

isolation. Managing these fisheries requires monitoring the activities of all users of the resources including fishers, buyers, brokers, wholesalers, and retailers, as well as government agencies and trade associations.

Management of the LRFF trade can be done at different points along the market chain, for example by managing the size and scope of the fishery itself (controlling the fishers), placing controls on the activities of the buyers, brokers, and wholesalers, (controlling the traders), and by market-based approaches (influencing the consumers).

Management of the fisheries per se can be done by controlling the input, i.e., amount of fishing (such as number of fishers or boats, open/closed seasons and areas) and equipment used (such as handlines rather than cyanide and prohibiting compressors which are frequently associated with cyanide use). Management can also be applied to the output, such as through quotas, bans on certain species, export controls and size limits.

Some form of input control is in place in some LRFF producing countries, although the level of compliance is not known and enforcement, with few exceptions, is nonexistent. Of the output controls, quotas have even more institutional requirements than input controls and have rarely been adopted. Export bans may have slowed, but not stopped, the export of one vulnerable species, the humphead wrasse. Size limits are in place in many countries but often do not cover species taken for the LRFF trade, while bans on the export of live fish have rarely been applied.

National control over LRFF fisheries has so far proved ineffective in most countries because the locations of both LRFF and subsistence fisheries are usually remote in many ways from decision makers, making implementation of management measures at the national level difficult if not impossible. Also, the close business relationship between traders and local officials has been identified as a major impediment to compliance and convictions for illegal activities. There may be more hope in local management by customary reef owners.

Given the low yields of LRFF that can be taken on a sustainable basis, however, it is questionable whether a well-managed LRFF fishery can be profitable, particularly when considered in the long term, as evidenced by the industry's present pattern of short-term fisheries moving progressively

farther from the market. At the same time, the public cost of properly managing such fisheries by any of the means above would be prohibitive. Economic analyses are clearly needed.

Trade standards, particularly use of best practices that encompass reefs, fish populations, and fishing communities, are needed to improve the conduct of the industry and help it move toward sustainability. Consumer awareness programs have potential to influence the eating habits of many LRFF consumers. The protection of vulnerable species through international conventions is a potential tool for trade control, although the implementation of such conventions has only recently been applied to commercially exploited marine fish species.

Aquaculture

Aquaculture, defined broadly as any intervention in the life cycle of aquatic organisms to increase production, is responsible for up to half of the LRFF trade. The focus is on groupers, which are preferred by most farmers in view of their high value. The largest producer is mainland PRC, followed by Taipei,China, Indonesia, Viet Nam, and Thailand, with a 2001 annual total of around 25,000 t. The majority, more than 60%, of these fish come from grow-out operations, in which small wild-caught fish are grown in cages to market size. Most are fed wild fish.

Full-cycle aquaculture, the rearing of fish from egg to market size, takes place mainly in Taipei,China, although there is increasing production from hatcheries in Indonesia. Other major producing countries are developing a hatchery subsector, but only a few species can presently be raised using hatchery techniques.

Recently, emphasis has begun to focus on sustainable grouper culture because of the high value of groupers in the LRFF trade and concerns about overfishing wild populations. The past five years have seen significant improvements in two major factors in sustainable grouper aquaculture: hatchery production of fingerlings and the development of pellet diets.

Overall, the grouper aquaculture industry provides important socioeconomic benefits to coastal communities throughout the region. Aquaculture at both hatchery and grow-out stages appears to be highly profitable. Backyard grouper

hatcheries in Bali have internal rates of return of 12–356%. Grow-out of grouper in cages and ponds in the Philippines brings returns on investment of 59% and 82%, respectively—far more than possible farming the more "traditional" crop, milkfish.

The main constraints to further development of grouper culture are insufficient numbers of small fish (from the wild or hatchery-produced) for grow-out; only a few species are available from hatcheries; erratic and possibly unsustainable supply of other fish (often bycatch from other fisheries) used for feed, and localized water pollution resulting from their use; low farmer acceptance of compounded feeds, and the high cost of pellet feeds; spread of fish diseases; and impact of culture operations on the environment. Fisheries for juvenile fish for grow-out contribute to local population depletions and spread of fish diseases. Finally, the use of fish to feed LRFF in areas where the same species are or were used for human food, means additional fishing pressure on and possible depletion of such food resources for local communities.

Institutional Aspects

In the Pacific-island subregion, a Pacific Regional LRFT (live reef fish trade) Initiative, spearheaded by the Secretariat of the Pacific Community, with the involvement of several nongovernment organizations (NGOs), has helped some countries to assess their LRFF resources and develop management and monitoring plans.

Several international NGOs, the Asia-Pacific Economic Cooperation (APEC) and the intergovernmental Network of Aquaculture Centers in Asia-Pacific (NACA), have undertaken activities at various levels—research, surveys, awareness programs, etc.—related to the LRFF trade.

Missing is a coordinating body to distil the information, minimize duplication of effort, and act as both a promoter and watchdog on the trade. A broad regional "trade" organization that includes all LRFF-producing countries would provide a large pool of experience and expertise, and attract assistance to accelerate research on solutions to some of the countries' dilemmas concerning LRFF fisheries.

Conclusions

There is inadequate information to understand fully the trends in and the full extent of the LRFF trade. Neither is there sufficient biological knowledge of the main species in the trade, the groupers, on which to assess their population sizes. Nevertheless, enough is known to conclude that the yields being taken on an individual reef basis are likely to be unsustainable and that this could have flow-on effects that affect the health of the reef ecosystems themselves, with long-term implications for the livelihoods that depend on them.

Overall, as currently practiced, LRFF fisheries are undesirable, not only because they appear to damage the reef ecosystems and thus the potential yields of other fisheries for the same and other species, but also because the short-term economic benefits they typically provide to source country communities have generally come at a high social—and sometimes health—cost.

Although there are many available management tools for this kind of fishery, most would not be cost effective because attainable yields of a sustainable LRFF fishery, equivalent to a few fish per square kilometer per day, are insignificantly small and the costs of monitoring high.

Aquaculture of some LRFF species, primarily full-cycle aquaculture based on hatchery production of seed fish, holds more promise of sustainability, despite a variety of constraints at present. Existing aquaculture operations are quite profitable. Their expansion should be based on hatchery production and attend to incipient ecological problems, such as pollution from feed and the use of other reef fish to feed the LRFF.

There are roles for a regional trade organization and for international and nongovernment organizations to encourage some self-regulation, act as watchdogs, and assist the trade to move from destructive to sustainable practices.

1 INTRODUCTION

CHARACTERISTICS OF THE LIVE REEF FOOD FISH TRADE

Live fish have long been traded around Southeast Asia as a luxury food item. The fish are displayed alive in aquaria in restaurants and markets. Consumers select individual fish that are then cooked and served in a restaurant of choice, or the fish are taken home to be prepared fresh. Chinese communities are the main consumers and the principal demand centers are Hong Kong, China; mainland People's Republic of China (PRC); and Taipei,China. Hong Kong, China, has become the main center where live fish are imported both for domestic consumption and for "re-export" to the PRC mainland.

Although trade in live fish has a long history, live reef food fish (LRFF) entered the international trade in substantial numbers only in the late 1980s to early 1990s.

Consumer preference is for one or more of such attributes as steaming well for best taste and texture; color—red is considered auspicious; and size—whether for a small family or a banquet. Some LRFF are particularly sought for the fine quality of their flesh. Another factor is time of year; demand and prices peak during traditional Chinese festivals. Wild fish are said to be preferred by consumers although taste tests indicate that it is difficult to distinguish wild from cultured fish.[1]

Differences in these factors have resulted in a wide spread of prices. At retail, LRFF fetch from US$5 to $180 per kilogram (kg), considerably more than the price of similar dead reef fish. Table 1.1 shows some recent average retail prices in Hong Kong, China.

[1] Omnitrak 1997.

Table 1.1: Average Retail Prices (March 2003) of Dead and Live Reef Food Fish in Hong Kong, China
(US$/kg)

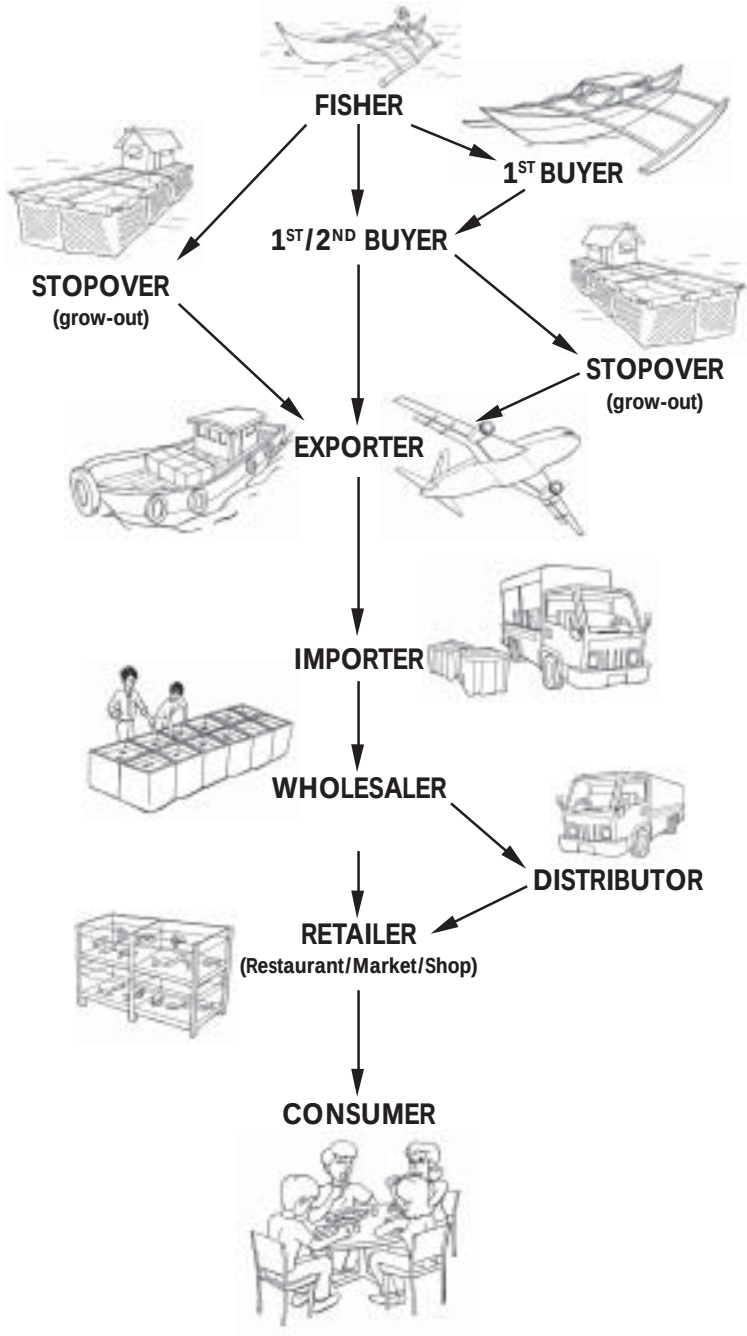
	Dead Fish	Live Fish
Humphead (Napoleon) wrasse	18.00	60.50
Orange-spotted (green) grouper	6.40	15.50
Brown-marbled (tiger) grouper	9.00	20.80
Giant grouper	18.00	21.00
Camouflage (flowery) grouper	9.00	22.60
Leopard coralgrouper	15.40	31.80

In part, the high prices also reflect the complex structure of the trade. Typically, the fish are bought from local fishers, or foreign businesses supply their own fishers. The fish may pass through several levels of trade and are usually held near the fishing grounds until sufficient quantities have been accumulated to pass on to the next stage, or for export. Exports are by sea or air depending on the source country, air connections, and other factors (Figure 1.1). Some 60% of the international trade flows into Hong Kong, China, but more than half of that is "re-exported" to mainland PRC. Plates 1-6 at the end of this chapter show various aspects of the trade.

Fish that are too small for market may be kept in floating cages and fed (called grow-out) until large enough for export. There is also a hatchery subsector, through which the fish are reared from eggs to market size in what is called full-cycle (or hatchery) aquaculture. The different stages of their life cycle at which fish enter the trade, summarized in Table 1.2, have important implications, discussed below, for the sustainability of the populations of these fish. Initially, all fish came from the wild. Nowadays, up to half the total volume of fish may enter the trade through aquaculture, primarily through grow-out of wild-caught fish, but with expanding full-cycle production of several species. Whether or not hatchery production will eventually remove the pressure from wild populations of some species, or simply increase consumer interest and access to them, is not known.

Until the 1980s, LRFF fisheries were mainly confined to areas in the South China Sea within easy vessel reach of ports in Hong Kong, China; mainland PRC; and Taipei,China. The market

Figure 1.1: Typical LRFF Trade Structure from Fisher to Consumer



expanded enormously during the 1990s. The nearby areas became depleted according to accounts from the industry, assessments of Hong Kong, China and South China Sea resources,[2] and as suggested by the higher costs incurred when vessels have to travel further from home ports, such as Hong Kong, China.[3] At present, LRFF are shipped by sea or air from sources of capture that are well into the Pacific and Indian oceans (Figure 1.2). The number of countries and territories involved in the trade has grown quickly and the trade has become a regional phenomenon.

Table 1.2: Fish Enter the LRFF Trade in One of Three Ways

Mode of Entry	Proportion of the Trade (%)
1. Wild-caught market-size fish, held for short period to acclimatize and await transport for export; essentially a capture fishery	50–70
2. Wild-caught, undersize and juvenile fish, held and fed in confinement for several months to more than one year until market size; a form of aquaculture, termed here *grow-out*	15–40
3. Reared from eggs in a hatchery and held and fed in confinement until market size; termed here *full-cycle aquaculture*	10–15

The lure of the LRFF trade lies in the perceived potential for high economic gains at each link in the chain of trade. In practice the gains are uneven among fishers, sellers, and traders for a variety of reasons, including fishers' ignorance of the value of fish caught, the relatively low prices sometimes given to fishers (e.g., in the Solomon Islands) the high transport costs incurred by traders, the high risks of transport, and vagaries in the economic situation (such as a downturn caused by the recent sudden acute respiratory syndrome [SARS] epidemic).

The international LRFF trade was worth around $350 million/year during 1999–2002. At its peak in 1997,[4] the volume of fish in the trade was estimated to be about 50,000 tonnes (t) at the

[2] e.g., Johannes and Riepen 1995; Barber and Pratt 1997; Butcher 1998; Pet-Soede and Erdmann 1998; and Cheung 2001.
[3] Patrick Chan, personal communication.
[4] Lau and Parry-Jones 1999.

retail end. Since then, the volume has declined to about 30,000 t. The actual quantities of fish captured, however, are probably much greater, given the sometimes considerable proportion of fish, averaging about 50%, that die before reaching the market.[5] Although air transport results in less mortality en route, many fishing grounds are far from airline routes, and mortalities associated with cyanide use or during holding prior to export are common to both sea and air transport.

The LRFF trade is not well monitored. In most countries, export figures are either unavailable or unreliable. On the import side, the Government of Hong Kong, China provides reasonable estimates of imports of each of the major fish in the trade, although there is substantial underreporting because vessels licensed in Hong Kong, China are not required to report their landings, and these account for a significant proportion of imports. The Government collects data informally from this exempt subsector, but imports by exempted vessels are still underreported by a significant factor (50% by government estimates). However, government data are only available from 1997 and re-exports to mainland PRC are not recorded.

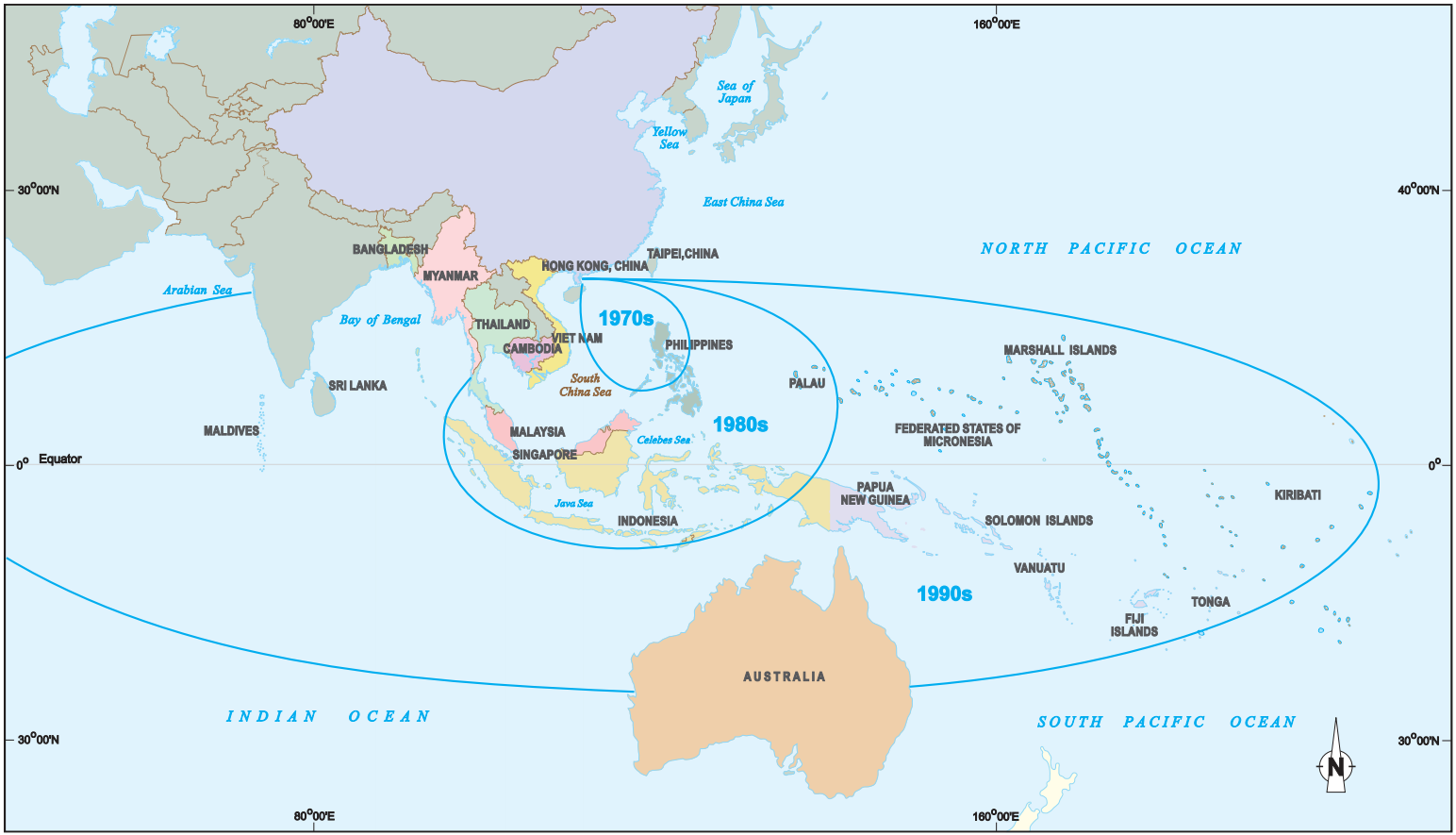
Major Issues

The LRFF trade first came to broad international attention in the mid-1990s on the publication of a report on the environmental, economic, and social implications of the trade.[6] A Cable Network News (CNN) feature on the report noted in particular its association with cyanide use. Cyanide is frequently used to catch fish for the trade in several areas, most notably the Philippines, eastern Indonesia, and eastern Malaysia. This method stuns the target fish, making them easy to catch, but it kills many target and nontarget fish and has also been shown to kill coral.[7]

Some species, such as the humphead wrasse, can only be taken efficiently with cyanide**.** For reef species that depend on healthy reefs for shelter and food, loss of reef structure means reduced abundance. Also closely associated with cyanide is the use of hookah breathing gear. Deaths and injuries associated with

[5] e.g., Johannes and Lam 1999.
[6] Johannes and Riepen 1995.
[7] Jones and Steven 1997; Jones and Hoegh-Guldberg 1999.

Figure 1.2: Source Countries for Live Reef Food Fish Imported into Hong Kong, China



Note: Boundaries are not necessarily authoritative.

The map depicts the expansion of the LRFF fishery in successive decades into both the Pacific and Indian Oceans. The western extent of the fishery in the Indian Ocean is the Seychelles (not shown). Viet Nam is an exception in the trends shown. The trade did not begin there until the 1990s.

hookah use by unskilled divers are common. Blast fishing is used in Malaysia and elsewhere to take bait for live fish or food to feed cultured fish. In some areas, including Malaysia and Indonesia, fish traps are camouflaged or weighted down with large pieces of living coral, again damaging reef structure.[8]

A major concern is the very real potential for overfishing these valuable reef resources. Continued overfishing means decline and, in extreme cases, local disappearance of target fish as well as disruption of the reef ecosystem with long-term negative implications for small-scale coastal fisheries. A recent analysis suggests that the Hong Kong, China trade alone is taking a significant proportion of the total potential yield of grouper from the Indo-Pacific region.[9] In some areas of Southeast Asia and the western Pacific the fishery has been characterized as "boom-and-bust" for the countries concerned, and "slash-and-burn" (a traditional form of agriculture) for the fishing companies, which move on as local resources become depleted.[10] Given that the groupers and other large reef fish taken by the trade are also important in many countries as a source of food and livelihood, including tourism, this concern is very real.

Most LRFF target fish appear to be particularly prone to overfishing because of their biology. Many are long-lived and slow to reach sexual maturation which means that populations are slow to replenish themselves. Fishers in some areas seek out the spawning aggregations of target fish, where large numbers can be caught with minimum effort, removing much of the breeding stock. And increasingly, fish are being caught before reaching sexual maturation, further eroding reproductive potential of affected species.

Some governments have responded to the perceived potential for high economic gain by increasing aquaculture production of high-value fish, through incentives for investment and for cash generation, and as a solution to overfishing (e.g., Malaysia and Indonesia). However, increased production often continues to depend on the grow-out of wild-caught juvenile fish, further depleting natural resources.[11]

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[8] Daw 2002.
[9] Warren-Rhodes et al., in press.
[10] e.g., Johannes and Riepen 1995; Sadovy and Vincent 2002.
[11] e.g., Galid 2003.

Social conflicts where resource owners, users, and traders cannot agree, and corruption at various levels beset the trade making enforcement difficult and bringing economic benefits to relatively few. To secure sufficient fish or to avoid local or national laws, illegal trade occurs across borders, such as between the Philippines and eastern Malaysia; live fish transport vessels easily avoid customs payments and inspections because of their flexibility of movement and ability to access remote areas.[12] There are also concerns by traders about securing steady access to resources and a constant supply of fish. Political and economic instability in some source countries injects an element of uncertainty in the continuity of trade and increases business risks.

Finally, because of the wide range of sources being used to satisfy the demand for LRFF, areas are sometimes inadvertently fished where ciguatoxic fish occur. These are fish that have become poisonous by consuming smaller fish containing natural toxins from eating certain algae. The condition in poisoned humans is known as ciguatera. Sporadic shipments of toxic reef fishes arriving in Hong Kong, China have resulted in large numbers of ciguatera poisoning cases, more than 400 reported cases alone in 1998.[13] This problem is likely to continue if there is no regulation of fish sources, because tests to identify ciguatoxic fishes are unreliable

Once the Asian regional economy improves, demand for luxury live fish is set to grow. According to reports from the Hong Kong, China-based industry, LRFF businesses there are already establishing new offices in mainland PRC in anticipation of expanding trade northward throughout the PRC as per capita income increases.

SCOPE AND OBJECTIVES OF THE BOOK

This book grew out of a recognized need to bring together, under one cover, a concise comprehensive overview of widely dispersed but valuable information on the LRFF trade. It is based on a series of reports by researchers directly involved in various

[12] e.g., Johannes and Riepen 1995; Daw 2002; Jose Ingles, personal communication.
[13] Sadovy 2001.

aspects of the trade. The book aims to summarize present understanding of the dynamics, problems, and promise of the LRFF trade for a range of stakeholders, from fishery officers, resource managers, and politicians to conservation groups and biologists. The book also aims to draw conclusions about the trade in terms of its viability, particularly its biological sustainability and the implications for the various stakeholders, and to identify gaps in data and knowledge.

Chapter 2 explores economic aspects of the trade including quantities and prices, a trade analysis, and macroeconomic issues. Chapter 3 examines the biological attributes of the fish resources used in the trade, their vulnerabilities and natural limitations, as well as the importance of monitoring fisheries based on them. The live grouper fisheries for the trade are placed in the perspective of the regional fisheries for traditional markets. Chapter 4 deals with social issues that have arisen in these relatively new fisheries, how these issues vary within different cultural contexts, the socioeconomic benefits and constraints of LRFF aquaculture, and the social legacies that result from LRFF fisheries. Chapter 5 addresses management and its importance and evaluates the various fisheries management and trade control options available or in effect. Chapter 6 explores the potential for and limitations of aquaculture to supply some of the demand for live reef food fish. Chapter 7 summarizes the relevant activities of various regional organizations in preparing for and addressing problems of the LRFF trade and proposes roles for a broad regional LRFF trade organization and for regional donors/development partners. The final chapter draws conclusions and identifies options for the way forward.

Plate 1. Some of the many methods used to catch live fish

Upper left: Push nets are one of many gears widely used in shallow waters to take small groupers for grow-out (Photo: Sadovy/APEC). *Upper right*: Indonesian push-net fishers wading home, small live fish suspended from the floats they trail (Photo: Sadovy/APEC). *Lower*: Plastic containers for mixing (large) and dispensing (small) cyanide solution in Indonesia. Larger bottle is weighted for rapid disposal overboard to avoid detection (Photo: Sadovy).

Plate 1 (cont.).

Upper: Small traps used to catch juvenile grouper for grow-out in mainland PRC (Photo: Lau/APEC). *Lower*: Home and outrigger boat of a live fish fisher in the Philippines (Photo: Sadovy/SCRFA).

Plate 2. Grow-out of undersize fish to market size

Upper: Floating net cages in coastal waters, southern PRC (Photo: Sadovy/APEC). *Lower left*: Wild-caught juvenile humphead wrasse (about 35 cm) being grown-out in Indonesia (Photo: Sadovy/SCRFA). *Lower right*: Mixed fish bycatch typically used to feed marine fish during grow-out (Photo: Lau/APEC).

Plate 3. Packing live fish for air transport

Upper: Live fish are packed in bags and oxygen added for air shipment (Photo: McGilvray). *Lower*: Bags of live fish are packed in polystyrene boxes and placed in cardboard boxes for air shipment (Photo: McGilvray).

Plate 4. Transporting live fish

Upper: Insulated and molded plastic bins are aerated or oxygenated and can carry up to 300 kg of live fish by air. (Photo: McGilvray). *Lower*: Shipment of live fish in boxes for air transport; fish are packed at a ratio of about 1:3 fish to water by volume (Photo: McGilvray).

Plate 4 (cont.).

Upper: Small live fish transport vessel (blue, in background); these often also carry small dories for fishing operations. Bigger vessels can exceed 20-tons capacity (Photo: McGilvray). *Lower*: Small aeroplane for inter-island live fish transport (Photo: McGilvray).

Plate 5. Landing/wholesale and retail sale of live fish in Hong Kong, China

Upper left: Weighing and off-loading live fish on arrival (Photo: Sadovy). *Upper right*: Live groupers on public display in Sai Kung, a large seafood center (Photo: Sadovy). *Lower*: Live fish on sale in a major local supermarket (Photo: Sadovy).

Plate 6. Retail end of the trade in Hong Kong, China.

Upper: Live fish on public display; a typical sight in seafood restaurants (Photo: McGilvray). *Lower*: Fish are selected by the customer and then steamed fresh, Cantonese style (Photo: McGilvray).

2 ECONOMIC AND TRADE ISSUES

VOLUME OF TRADE

Although the LRFF trade has been flourishing for several decades, economic and trade information is scanty. In the main trading center, Hong Kong, China, data on the LRFF market prior to 1997 were coarse. Both marine and freshwater live fish were categorized broadly as either food or ornamental fish. The Harmonized Code System (HCS) used in Hong Kong, China to monitor food imports was improved in 1997 to identify live reef food fish categories. Refinement of the HCS in 1999 enabled LRFF imports to be distinguished by key species and country of origin, further improving monitoring capacities, although inaccuracies persist. Trade agreements between Hong Kong, China and mainland PRC have meant lower tariffs on LRFF entering PRC through Hong Kong, China than on those entering PRC directly. The PRC has now joined the World Trade Organization and LRFF may possibly enter mainland PRC directly without a tariff. At present, there is limited capacity to record and monitor such imports or trade between Hong Kong, China and mainland PRC.

The following discussion is based mainly on Hong Kong, China trade in LRFF, for which the most information is available.

Total Import Volumes

Estimates of annual imports of LRFF into Hong Kong, China are derived from formal data collected by the Census and Statistics Department (CSD) and data provided voluntarily by traders to the Agriculture, Fisheries and Conservation Department (AFCD). Imports remained steady up to the mid-1990s although estimates of the annual total vary from 22,000–28,000 t[14] to 30,000–35,000 t.[15]

[14] Graham 2001a.
[15] Chan 2000a; Lau and Parry-Jones 1999.

The reliability of these estimates continues to be hindered by the underreporting of imports because there is no requirement for the approximately 100 Hong Kong, China-licensed live-fish transport vessels to declare imports by sea. The voluntarily declared imports for this fleet are estimated by AFCD to be underreported by nearly half.[16] The analyses presented in this section are based on both CSD data, which mainly reflect imports by air, and AFCD data. The AFCD data do not identify the source country and were available only from 1998. Declared (CSD and AFCD) imports of LRFF into Hong Kong, China for 2002 were more than 13,000 t, with total imports more likely 15,000–20,000 t.[17] An approximate mid-point estimate of 18,000 t is used to determine trade values in the next section.

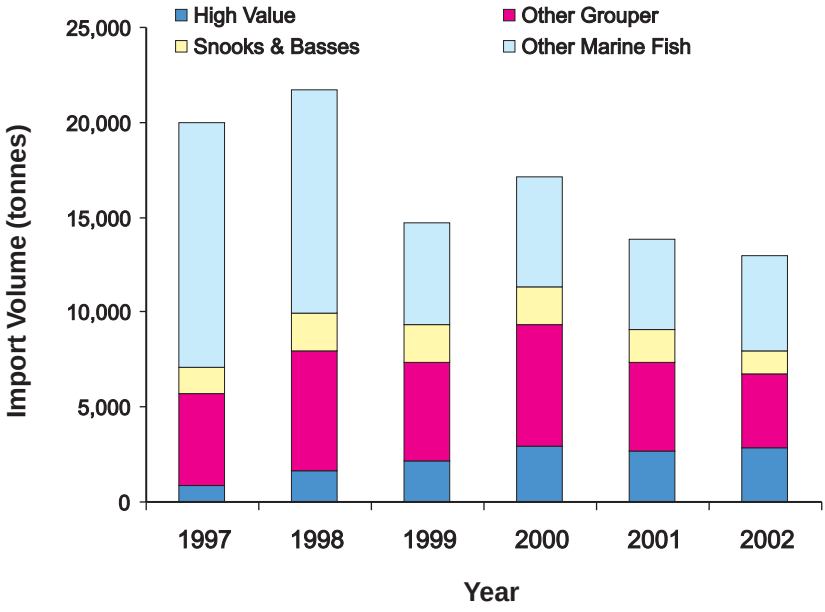
During the 1960s, the market for live food fish expanded in concert with Hong Kong, China's increasing wealth. The market for LRFF at that time was dominated by species readily available around Hong Kong, China and the South China Sea, the most favored being the Hong Kong (or red) grouper. As fish populations on local reefs began to show signs of depletion, Hong Kong, China-based companies moved further afield, sourcing live reef fish from the Philippines, Malaysia, and Viet Nam. Low-value species imported from these nearby countries began to dominate and, until the mid 1990s, made up more than 50% of all live food fish imports. The low-value groupers (i.e., orange-spotted, Malabar, greasy, and duskytail groupers), and high-value groupers and wrasses accounted for approximately 30% and less than 10% of all imports, respectively, during this time.

The Hong Kong, China and mainland PRC economies remained fairly robust for the duration of the financial and economic crisis in East and Southeast Asia that began in 1997, as evidenced by the September 1998 peak in the Hong Kong, China consumer price index (CPI). Moreover, the LRFF trade in Hong Kong, China may have been cushioned against the economic crisis in the early stages by the strength of its currency against the currencies of all main importing countries depreciating against

[16] McGilvray and Chan 2001; AFCD, communication to authors.
[17] Author's (FM) observations.
[18] The Hong Kong, China dollar is pegged against the US dollar at a rate of HK$7.8 = US$1.0. In 1997 and 1998, the Philippine Peso fell by 10% and 30%, respectively, while the Indonesian Rupiah fell by 15% and 70% in these years.

the HK$ in 1997 and 1998.[18] By December 1999, however, in the wake of the economic crisis, Hong Kong, China's CPI had declined by 6.8%. Total declared imports of LRFF declined by approximately one third in 1999. Most affected were the "other marine fish" and "other grouper" categories.[19] The proportion of "snooks and basses" has remained steady since 1997, while that of high-value species has almost trebled. In terms of volume, the latter have increased gradually from around 1,000 t to 2,500 t annually (Figure 2.1).

Figure 2.1: Total Reported Imports of Live Reef Food Fish into Hong Kong, China in 1997–2002



Note: High-value species include humpback grouper, humphead wrasse, giant grouper, leopard coralgrouper, and spotted coralgrouper. Other grouper include the orange-spotted, brown-marbled, camouflage, and other groupers. Other marine fish include wrasses and parrotfish, mangrove snapper, and other fish.

Source: Hong Kong, China Census and Statistics Department and the Agriculture, Fisheries and Conservation Department.

[19] A list of all species that make up the trade in LRFF is contained in Lee and Sadovy (1998).

Market Trends

In general, the market, as shown from CSD data, has contracted somewhat over the past 5 years, becoming more focused on fewer species—primarily the high-value and mid-priced groupers. The main causes of these past and likely future market shifts are thought to be the following.

Change in Mode of Transport

Overall improvements in transport technology and access to air transport have helped to increase imports of high-value species. The cost of air transport is becoming increasingly competitive with that of sea transport (see below; 60% of all LRFF are now transported by air), which favors countries like Australia. Australia has greatly increased exports of live coralgroupers to Hong Kong, China since 1999 (see Figure 2.2).

Change in Level and Nature of Demand

There has been a decline of some 40% in the reported LRFF market since 1998. This falling demand has led to overall weak retail prices, making the purchase and transport of lower-priced fish that make up the bulk of imports financially nonviable, resulting in Hong Kong, China traders' reducing the volume of imports by sea. This response has been reinforced by relative increases in variable costs (fuel, fish feed, ship hire, and maintenance and insurance) of transporting fish to markets by sea.[20] Consumer preferences for different kinds of fish or for wild versus cultured fish may also be changing.

Changing Fish Production Methods

Increasing adoption of aquaculture methods favors the kinds of fish that are amenable to and desirable for such operations, i.e., easily spawned, fast-growing, hardy kinds of groupers. These are mainly in the lower-priced "other grouper" category. Grow-out of undersized wild-caught fish has expanded

[20] Patrick Chan, personal communication.

considerably in Southeast Asia (but has declined in Hong Kong, China)—partly in response to overfishing of market-size fish—using fish collected locally and occasionally imported from Taipei,China. While PRC and Taipei,China do use full-cycle culture methods, both also import wild-caught juveniles for grow-out. The increase in hatchery production is seen as a positive industry development, but there is growing concern over the parallel increase in grow-out of wild-caught juveniles for market.[21]

Health Concerns

The downturn in general business because of the international SARS epidemic which became a major health problem in Hong Kong, China in the first half of 2003, appears to have had a temporary, slight impact on consumer prices in the LRFF trade, but a greater impact on exports from source countries. For example, newspaper reports[22] indicated that the fishery in north Queensland, Australia was severely affected. The sudden drop in demand resulted in a 57% reduction in price and a reduction in weekly export volume from 25 t to 2 t, sparking a crisis for the LRFF fishers and associated industry in Australia. It also illustrates the vulnerability of supply countries to events and economic conditions in the major demand center.

A related concern is fish poisoning, occasionally fatal, from ciguatera, caused by toxins that accumulate naturally in fish in certain reefs. Ciguatera is a significant human health problem for both exporting countries and for traders because of its often unpredictable spatial and temporal occurrence and because there is no reliable diagnostic test.[23] While there are known hotspots for ciguatoxic fishes in the central and southern Pacific, trade is still conducted with these islands[24] in species often associated with ciguatera (e.g., camouflage grouper, brown-marbled grouper, humphead wrasse, and coralgroupers).

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[21] In some regions, market-size coralgrouper have all gone; only juveniles are caught and grown-out locally, and sold when they attain market size. Authors' (GM, YS) observations; Sadovy 2000.
[22] Barker 2003; Seafood.com News 2003.
[23] Dalzell 1992.
[24] Lewis 1986; Sadovy 2001.

There has been a marked increase in confirmed cases of ciguatera in Hong Kong, China in the 1990s.[25] The real number of victims in 1998 was likely much higher than the more than 400 cases reported because many incidents go unreported or are misdiagnosed as food poisoning.[26]

Affected source countries may find it difficult to market their fish, even if relatively few of their reefs yield ciguatoxic fishes. Importing countries and traders cannot easily protect themselves from bringing toxic fishes into demand centers, with serious consequences for consumers and prices.[27] For species likely to be ciguatoxic, there is a preference to trade smaller individuals because these are less likely than larger fish to be affected. This means that such species tend to be traded while still in their juvenile phase with no chance to contribute to replenishment of their populations.

Ciguatera is not going to go away. The problem needs to be addressed by both importing and exporting countries. One way is for affected countries to follow hazard analysis critical control point (HACCP) guidelines (of the United States Food and Drug Administration). Another is for closer coordination and cooperation between traders or with their umbrella organizations (further discussed in Chapter 7).

Civil Unrest

Civil unrest, mainly because of separatist movements, in Indonesia and the Philippines, has undoubtedly reduced access to some fishing grounds and rendered live fish transport risky across a wide area. These conditions are unlikely to change in the short to medium term.

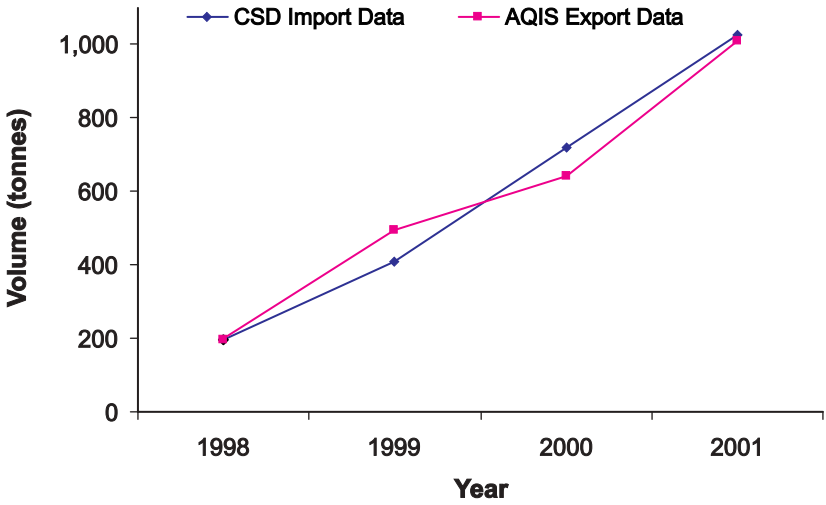
Data Discrepancies

Corroborating Hong Kong, China import records against source country export records is difficult. Even in Australia, where disaggregated live reef export data are collated by the Australian Quarantine Inspection Agency, discrepancies exist between

[25] Sadovy 2001.
[26] Chan et al. 1992.
[27] Sadovy 2001.

export and import data (Figure 2.2).[28] For most source countries, LRFF exports are not disaggregated at a species level, species are misreported and underreported, and nonlive reef fish may be included in export data. At an aggregate level, "official" exports from source countries in Southeast Asia are usually considerably below official estimates of imports into Hong Kong, China.[29] The discrepancy is attributed to the physical remoteness of fishing areas and the use of live-fish transport vessels, resulting in fish movements being unrecorded both leaving the source country and upon arrival in Hong Kong, China. Increased use of air transport has meant that where air transport is extensively used,[30] declared

Figure 2.2: Discrepancies between Official Data for Exports from Australia and Imports into Hong Kong, China of Leopard Coralgrouper in 1998–2001



Source: Hong Kong, China Census and Statistics Department and Australian Quarantine Inspection Agency (AQIS).

[28] Almost all Australian live reef fish exports are sent by air transport and 90–95% are leopard coralgrouper; all air imports into Hong Kong, China must be declared and are included in CSD figures.

[29] Bentley 1999.

[30] Air transport accounts for 40–70% of all LRFF imports from Indonesia (Pet-Soede and Erdmann 1998; Bentley 1999) and up to 90% of LRFF imports from Malaysia and the Philippines (Bentley 1999; Padilla et al. 2002).

imports into Hong Kong, China are likely to be now much closer to actual country exports.[31]

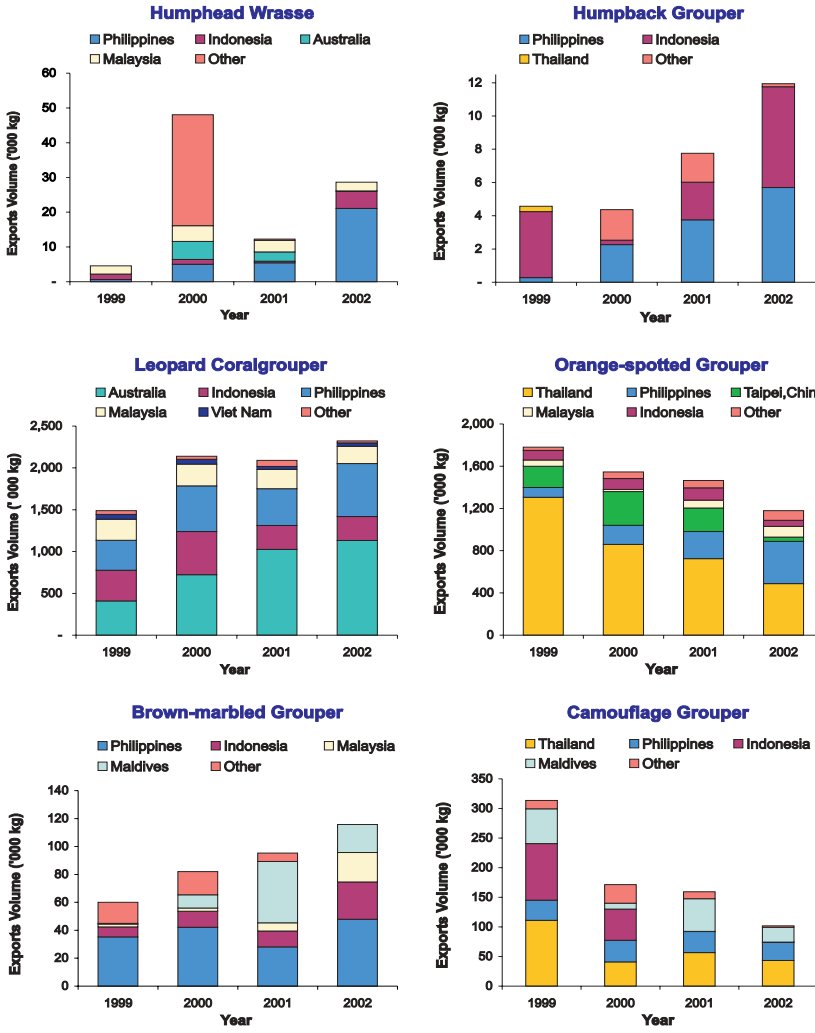
Import Volumes of Major Species by Country of Origin

The main exporting countries of wild-caught and farmed live reef fish are Indonesia; Philippines; Australia; mainland PRC; Malaysia; Thailand; Viet Nam; and Taipei,China. Indonesia, Malaysia, Philippines, and Australia are the major exporters of high- and medium-priced wild-caught live reef fish, while smaller quantities are exported from Thailand, Cambodia, Viet Nam and the Maldives[32] (Figure 2.3). Thailand and Taipei,China export large quantities of farmed grouper,[33] mainly orange-spotted grouper, while the PRC is the dominant supplier of other marine fish and snooks and basses. Infrequent and irregular exports of LRFF, mainly coralgrouper and other groupers have also been reported from Fiji Islands, Marshall Islands, PNG, Seychelles, Singapore, and Solomon Islands.[34]

The official (CSD) volumes of imports into Hong Kong, China of major high- and medium-priced groupers and humphead wrasse during 1999–2002 are shown in Figure 2.3. Indonesia and the Philippines are major suppliers, although exports of coralgroupers, orange-spotted grouper, and camouflage groupers from Indonesia have all declined during this period. Since 1999, total imports of coralgroupers have increased by more than 60%, with new Australian exports making up more than 85% of this increase, while imports of brown-marbled grouper have more than doubled. In contrast, imports of orange-spotted grouper and camouflage grouper have declined by 35% and 55%, respectively, during this period.

[31] Chan (2000b) estimates that around 65% of all LRFF imports into Hong Kong, China from major exporting countries arrive by air.
[32] Bentley 1999.
[33] Both hatchery produced and wild-caught grow-out fish.
[34] Johannes and Riepen 1995; Shakeel and Ahmed 1997; Yeeting 1999; Johannes and Lam 1999; IMA Hong Kong, China, unpublished data.

Figure 2.3: Volume of Imports for 6 Major Species Imported into Hong Kong, China, by Country of Origin in 1999–2002



Note: Those countries that make up the "other" category vary for each species. In most cases, these countries do not export regularly or on an annual basis. Countries that export several species include Cambodia, PRC, Singapore, Thailand, and Viet Nam.

Source: Hong Kong Census and Statistics Department and International Marinelife Alliance (Hong Kong, China).

TRADE VALUE

Estimates of trade values were calculated by multiplying recorded monthly imports of each species or species grouping by the average monthly price for that species or grouping. Data on imports have been compiled by the International Marinelife Alliance (IMA) Hong Kong, China, from the CSD and AFCD, while data on prices are collated from IMA surveys of wholesale and retail outlets in Hong Kong, China. In the case of the categories for other marine fish, snooks and basses, and other grouper species, where average monthly prices are not collected by IMA, average prices collated monthly by the AFCD from wholesale and retail markets in Hong Kong, China, have been used.[35]

Total Gross Value of Trade

Under the HCS, data on some grouper species remained aggregated until the system was refined in 1999. It was impractical to estimate gross retail values of the Hong Kong, China LRFF market prior to 1999, because retail prices for the aggregated species differed markedly. However, selected species, such as the leopard coralgrouper, can be used to examine the effects of any economic trends on market values.

Changes in market values of leopard coralgrouper since 1997 were examined by deriving a real value index. The index was derived by first dividing the total retail value of imports by the total volume of imports to obtain an average retail price for the years 1997–2002. Average prices were converted to "real" prices using Hong Kong, China CPI data (October 1999 = 100). Using 1997 as the base year, the average real price for each year was divided by the base year average price to calculate a real value index for that year. Assuming that increases in coralgrouper imports since 1997 (Figure 2.3) are in response to increased demand—which offset the impact of excess supply on prices—and improved

[35] For the snooks and basses, wrasses and parrotfish, other grouper, and marine fish categories, retail figures calculated for 2000–2002 are based on AFCD wholesale averages for a selection of fish in each grouping. Average mark-ups for other species are used to calculate retail prices and total retail value for the groupings.

transportation, the real market price for leopard coralgrouper declined by 30% during 1997–2002 (Table 2.1).

Table 2.1: Average Real Price and Real Value Indices for Coralgroupers in 1997–2002.

Year	Average Real Price ($)	Value Index
1997	73.95	1.00
1998	65.80	0.89
1999	60.80	0.82
2000	61.15	0.83
2001	57.35	0.78
2002	51.75	0.70

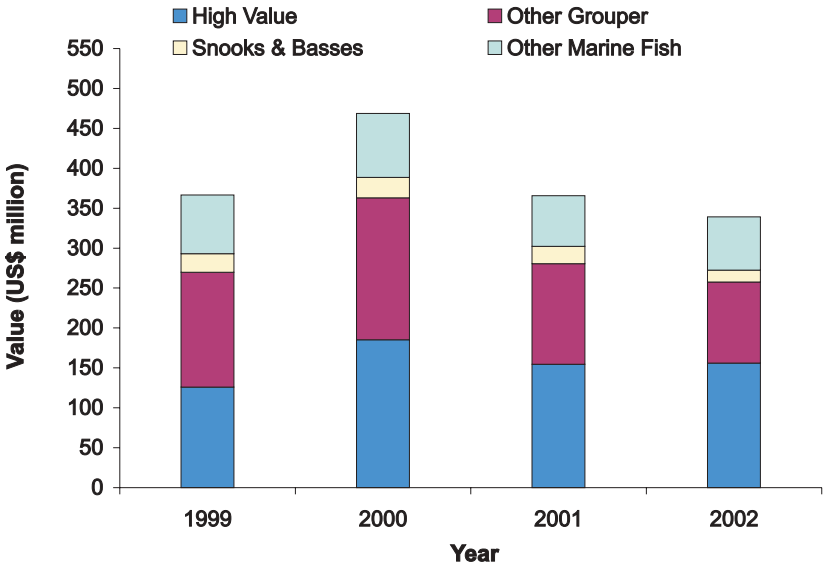
Note: Average real price is calculated by dividing total retail value by total import volume. Real value index is calculated by dividing yearly average prices of coralgroupers by base year (1997) average price.

Source: Hong Kong Census and Statistics Department and International Marinelife Alliance (Hong Kong, China).

The total gross "real" retail value (Hong Kong, China CPI; October 1999 = 100) of the LRFF market in Hong Kong, China remained relatively constant at about $350 million during 1999–2002, with the exception of 2000 (Figure 2.4). Imports of high-value species, which rose in weight from 14% to 22% of all imports, rose in total market value from 32% to 46% over this period. Imports of mid-priced other grouper species, fell in weight from 36% to 30% and in value from 40% to 30% over the period. As a proportion of both imports and market value, other marine fish and snooks and basses remained steady.

Scaling up from the official LRFF import figure of 13,000 t in 2002 to the estimated total imports into Hong Kong, China of about 18,000 t gives a gross "real" retail value of $486 million. Assuming that Hong Kong, China represents around 60% of total trade, the overall retail value of the regional trade was some $810 million in 2002.

Figure 2.4: Total Retail Value ($) of LRFF Imported into Hong Kong, China, during 1999–2002



Note: High-value species include humpback grouper, humphead wrasse, giant grouper, leopard coralgrouper, and spotted coralgrouper. Other grouper include the orange-spotted, brown-marbled, camouflage, and other groupers. Other marine fish include wrasses and parrotfish, mangrove snapper, and other marine fish.

Source: Hong Kong, China Census and Statistics Department and the Agriculture, Fisheries and Conservation Department.

Retail and Wholesale Prices (Hong Kong, China and Mainland PRC)

Demand for live fish in Hong Kong, China coincides closely with events on the Chinese lunar calendar and is observed to peak during traditional Chinese festivals, notably Chinese New Year (February), Mother's Day (May), the mid-autumn festival (August/September) and Winter Solstice (December).[36] These festive periods, especially Chinese New Year, correspond with higher than normal wholesale and retail prices for all high-value and some medium-priced fish. Figure 2.5 shows wholesale and retail prices for six major species for 1999–2002, both for wholesale

[36] Li 1996; Lau and Parry-Jones 1999.

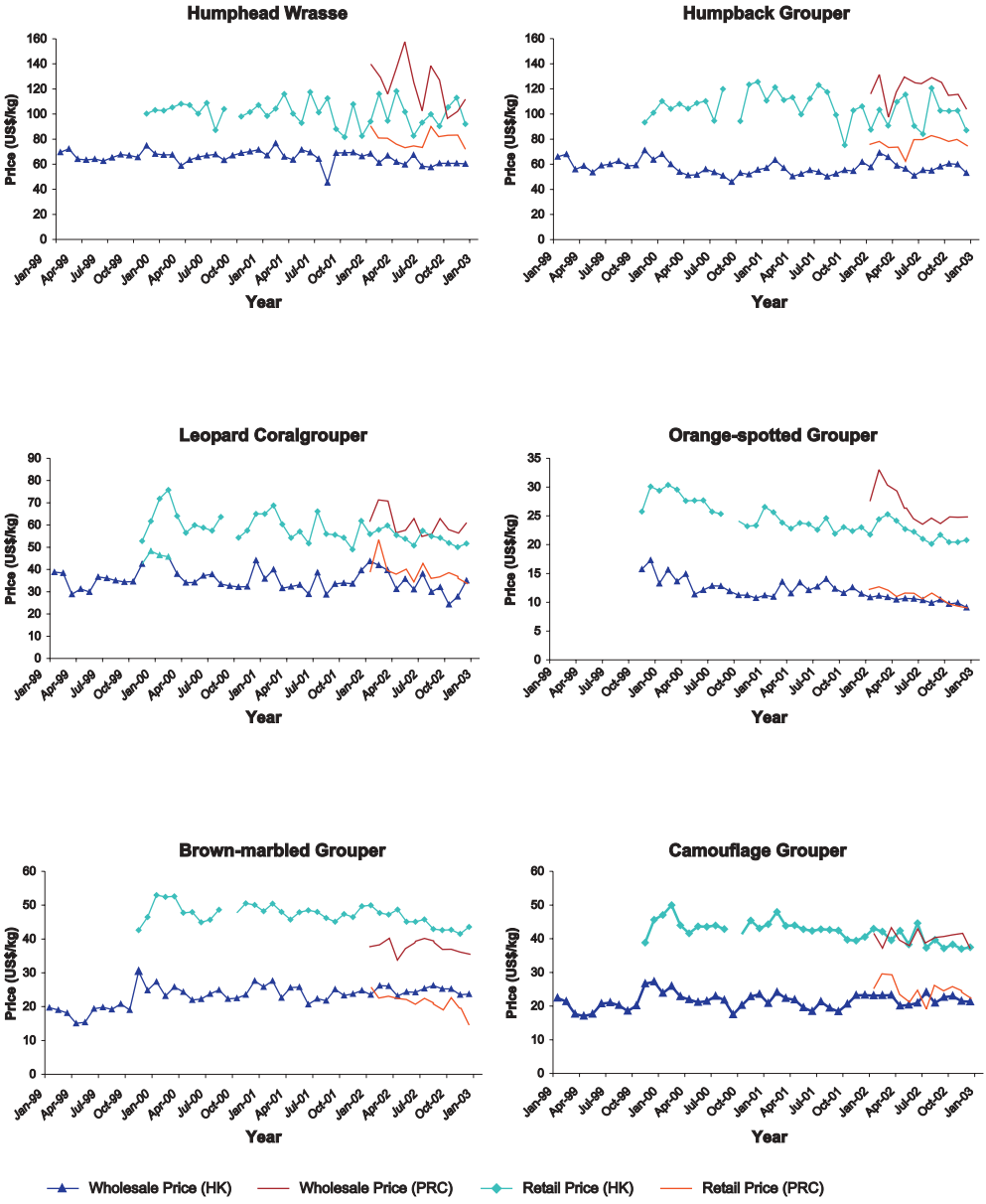
markets and restaurants in Hong Kong, China and mainland PRC (Guangzhou and Shenzen). While price peaks during festive periods are evident for all species, overall, prices have trended downward for the leopard coralgrouper and the green, brown-marbled, and camouflage groupers. Although humpback grouper and humphead wrasse prices fluctuate more widely, the price trends are stable. During the period, retail prices for humpback grouper averaged $82–118/kg, for humphead wrasse $75–125/kg, and for leopard coralgrouper $50–75/kg. Not all species command such high prices; retail prices for the popular orange-spotted grouper in this period were $20–31/kg.

There is a mark-up of 100–200% on wholesale prices in Hong Kong, China, because of the high rental costs of commercial property. The extent of the mark-up also depends on the restaurant's reputation and location and the desirability of the LRFF purchased. Both wholesale and retail prices are on average higher in mainland PRC than in Hong Kong, China. Most fish sold in mainland PRC come from Hong Kong, China[37] and the transfer attracts a small levy. This and the increased transportation costs contribute to higher wholesale prices in the PRC. Higher retail prices in Shenzen and Guangzhou are attributed to higher levels of economic growth being experienced in the PRC in recent years and higher relative status attached to consumption of LRFF in the PRC.

Historically, there was a considerable difference between wholesale and retail prices for cultured and wild-caught individuals for such species as orange-spotted grouper. This difference is often attributed to consumer perception that cultured fish, which spend at least part of their life being fed in captivity, do not have the same taste and flesh qualities as a wild-caught fish of the same species.[38] This situation has changed in the past few years. For example, the proportion of cultured orange-spotted groupers has increased to 95%; consumers now regard all orange-spotted groupers as being cultured.

[37] It is estimated that 55–60% of all LRFF imports into Hong Kong, China are "re-exported" to mainland PRC (Chan 2000a).
[38] OmniTrak 1997.

Figure 2.5: Wholesale and Retail Prices for 6 Major Species Sold in Hong Kong, China in 1999—2002.



Note: Retail prices are only available from Novermber 1999. Prices are also shown for selected species from markets in mainland PRC (Shenzen and Guangzhou).

Source: CSD, AFCD, and IMA Hong Kong, China.

Wholesale or Beach Prices (Exporting Countries)

The beach price refers here to the amount paid by the buyer for a fish when it reaches shore, just prior to export. Higher-value fish are usually graded either as undersize (<500 g), good or "plate" size (500 g to 1 kg), oversize (>1 kg) or per "piece" (>1.5 kg). Both wholesalers and exporters in source countries and importers in Hong Kong, China pay higher prices for plate-size fish, while oversize fish fetch a slightly lower price. In countries where undersize fish are traded, the price is usually around one quarter of the price paid for a good size fish.[39] In Australia, coral groupers less than the legal minimum length of 38 cm are rejected by wholesalers, while in the Philippines and Indonesia, where size limits are not enforced or not in place, all fish are purchased and fish that are undersize or not ready for market are moved to grow-out cages where they are held until they reach plate size. Fishers also may catch small fish for grow-out.

Payment may be made directly to a sole fisher or paid to a fishing operation that employs several fishers. The export price is generally the amount paid to the exporter by the overseas buyer, usually based in Hong Kong, China, and will reflect costs incurred by the exporters to purchase fish from a broker/dealer, where applicable, as well as any holding and transportation costs incurred by the exporter.

Table 2.2 depicts the average beach prices received by fishers in the major exporting countries for which data are available. The high prices paid for humphead wrasse in the Philippines and Malaysia recognize their proximity to market and the use of live-fish transport vessels to ship them to market. In Australia, the minimum legal size of 75 cm for humphead wrasse makes the use of air transport bins cost prohibitive because the volume of water displaced.[40] The significantly lower prices paid to Indonesia fishers for high-value species is notable in that it does not reflect the high retail prices paid for these species. The similar price for leopard coralgrouper in Australia, Malaysia, and the Philippines is deceptive in that the lower price range refers to

[39] Padilla et al. 2002.

[40] A voluntary code of conduct between the fishing industry and exporters, established in 2002, resulted in an end to the export of humphead wrasse.

Table 2.2: Average Beach Prices ($) Paid to Fishers for Selected Species in the Main Exporting Countries, 1999–2001

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

[a] Beach price paid per piece.

[b] Total price paid by wholesaler/exporter. Fisher receives approximately 30% of total price and dealer 70% (Palawan Council for Sustainable Development).

[c] Price varies depending on location; fishers in some areas receive less than half of the price paid by dealers in other parts of Indonesia (Erdmann and Pet 1999; Indrawan 1999; Country Status Overview 2001).

[d] Total prices paid to owner of vessel. Fisher receives 20% of market value for all species (G. Muldoon, unpublished data).

[e] Lower price ranges are for undersized fish (< 0.5 kg) for grow-out. Upper range is for good size fish (0.5–1.0 kg) ready for market (Chan, unpublished data).

[f] Lower price ranges are for undersized fish (< 0.5 kg) for grow-out. Upper range is for good size fish (0.5–1.0 kg) ready for market. For fish greater than 1.0 kg, price is paid per piece (Bentley 1999).

[g] McCullough and Phung Giang (2001); IMA Viet Nam (unpublished data).

[h] Lower price ranges are for smaller fish for grow-out. Upper range is for good size fish (0.5–1.0 kg) ready for market (Chan, unpublished data).

Notes: These data have been verified where possible by the Hong Kong, China, Chamber of Seafood Merchants. Prices do not take into account any other deductions made by the buyer for debts owed. Blank entry means no data available.

undersize fish in the latter two countries. On occasion, Filipino fishers are paid a higher price than that paid to Australian fishers, although Philippine catch rates are considerably lower than those in Australia.[41]

Finally, these prices do not recognize any obligations the fisher has with the dealer to whom they sell their catch. The complexity of the market chain and the diverse relationship between fishers and dealers/buyers in different countries means that comparing beach price across countries is difficult.[42]

Value Adding

In some countries, the advent of the LRFF trade has represented an alternative high "value-added"[43] fishery. Value-adding opportunities depend on whether or not subsistence or commercial fisheries have been supplying LRFF species to existing domestic or international markets. In Australia, the commercial reef-line fishery traditionally marketed its catch of coral reef fish as either frozen or whole chilled fish. Supplying the same species to the LRFF market yields prices 2–4 times higher. During 1999–2002, prices for live coralgrouper were 75–220% higher than for frozen product, while for humpback and brown-marbled grouper and humphead wrasse, live fish prices were 250–350%, 150%, and 200% higher, respectively, than frozen fish prices. In Indonesia, fishers may earn 200–2,500% more for live fish than comparable dead fish, with benefits flowing along the market chain,[44] while in Viet Nam, prices for live coralgroupers are 300% higher than for frozen.[45]

The potential for value adding to the existing catch is not always realized. In the Solomon Islands, fishers receive only 25% more for LRFF species than when they supply the same species to fresh fish markets in Honiara.[46]

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[41] Padilla et al. (2002) estimate that fishers on Coron catch on average 0.4kg of fish/hour while Mapstone et al. (2002) estimate that Australian fishers catch 6–10 fish/hour, weighing >600g, i.e., at least 3.6 kg/hour.

[42] Bentley 2002.

[43] *Value added* is the difference between the revenue earned through the sale of the product and the amount paid by that firm for products supplied by other firms that are required as intermediate inputs.

[44] Erdmann and Pet-Soede 1997.

[45] McCullough and Phung 2001.

[46] Donnelly et al. 2000.

ANALYSIS OF THE TRADE

Capital Investment

Capital investment in fishing vessels and gear varies across countries. In Australia, capital costs range from $100,000 to $450,000. This contrasts with the average investment in the Philippines of $700 for smaller operations, and up to $2,000 for larger boats capable of travelling farther and supporting more fishers.[47] Comparable investment costs and financial arrangements to those in the Philippines exist in Indonesia. Exporters and dealers usually extend financial assistance to fishers to enable such investment.

The main costs incurred by dealers/brokers and exporters in establishing LRFF capture and export operations are in the construction of the land-based holding facilities or floating cages, and purchases of vessels, motors, and other fishing equipment.[48] Identifying these costs is complicated by the trading structures within and between countries that involve several parties between sea and restaurant (see Figure 1.1).[49] Floating cage construction costs in Indonesia are estimated to be around $2,500 per unit while in Viet Nam these costs range from $800 to $1,200.[50] In the Philippines, fish for grow-out are held in floating cages while fish ready for export are held in floating cages and land-based facilities; cage capital costs are estimated to be approximately $1,250.[51] Capitalization of land-based facilities in the Philippines is estimated at $25,000–30,000 while in Australia, such costs are around $200,000.

[47] Padilla et al. 2002.

[48] Dealers and exporting companies usually provide fishers with fishing equipment on a loan basis with repayments deducted directly from fishers' wages or catch revenue until the loan is repaid. During difficult times, fishers are often extended credit to supplement living costs (Padilla et al. 2002).

[49] Bentley 1999.

[50] Bentley and Indrawan 1999; IMA, Viet Nam.

[51] Baliao 2000. Floating cage configuration usually consists of 4–6 adjoined cages, each 3m x 3m x 5m in size.

Transportation and Holding

There has been a marked increase in the volume of fish being transported to Hong Kong, China markets by air from all major exporting countries. About 60% of all LRFF imported there now arrive by air.[52] From Indonesia, almost 40%—in some areas up to 70%—of all LRFF are sent by air,[53] while for Australia, Malaysia, and Philippines, nearly all LRFF exports are delivered to Hong Kong, China by air.[54] Thailand and Viet Nam also rely heavily on air transport, with up to half of all LRFF exports being transported by this means.

The modes of air transport differ widely. LRFF exported from Southeast Asia are transported in oxygenated plastic bags packed in polystyrene boxes, while exports from Australia are in large moulded plastic aerated or oxygenated bins. The latter can hold up to 300 kg of fish in $1m^3$ of water; approximately 5 times the capacity of the polystyrene boxes.

The supplanting of traditional sea transport by air transport is seen as potentially important. On the one hand, there may be less ecological impact from, e.g., a LRFF fishery that ships small quantities frequently by air, with lower holding mortality and less need to feed fish. With fewer fish required per shipment, opportunities for a small-scale fishery that is both economically and ecologically viable present themselves.

On the other hand, the reduction in transportation times from weeks to days and improvement in air transport technology have resulted in much lower rates of mortality overall,[55] reduced investment risks by importers, and improved cash flows for both importers and exporters. These factors are likely to favor expansion of the present often boom-and-bust practices of the trade.

Cage maintenance and associated holding costs (wages, feed), while generally low, are difficult to quantify and vary according to the length of time fish are held before export. Holding times for LRFF sent by air are around 7–10 days from first sale,

[52] Chan 2000b.
[53] Pet-Soede and Erdmann 1998; Bentley 1999.
[54] Bentley 1999; Padilla et al. 2002.
[55] Mortality when using transport bins is reported by exporters and importers to be less than 5% on average, as opposed to between 30-50% for sea transport (L. Peterson, personal communication).

including conditioning of fish during transit, while the greater volume of fish required to justify the use of a live-fish transport vessel means longer holding times and higher holding costs (Table 2.3).

Wealth and Income Distribution

In Australia, fishers retain a greater percentage of the final value because they do not bear the variable costs associated with the fishing activity (i.e., hooks, bait, food, and fuel). Filipino fishers must not only meet these costs but also pay instalments to financiers for debts for capital equipment; costs are deducted from the catch values before payment to the fishers (Table 2.4). Australian boat owners, effectively brokers, retain a smaller percentage of the final value than do their Philippine counterparts

Table 2.3: Transportation and Operating Costs by Mode of Transport for Main Exporting Countries

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

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

Note: Blank entry means prices are not available for that country or that mode of transport is not an option from that country.

Table 2.4:
Wealth and Income Distribution along the Market Chain, Australia and the Philippines, Based on Average Monthly Retail and Wholesale Values ($) in Hong Kong, China for Leopard Coralgrouper, February 2001

Australia (Great Barrier Reef)

	Fisher	Boat Owner	Exporter	Importer/ Retailer	End User	Final Value
Share of Gross ($)	3.50	12.10	24.40	8.65	20.20	68.85
Share of Gross (%)	5.10	17.60	35.40	12.60	29.30	100.00
Net/kg ($)	3.50	2.40 [a]	9.75 [b]	1.75 [c]	10.10 [d]	27.50

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

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

Philippines (Coron)

	Fisher	Dealer	Exporter	Importer/ Retailer	End User	Final Value
Share of Gross ($)	7.80	15.70	11.80	9.90	23.60	68.80
Share of Gross (%)	14.30	22.90	14.30	14.30	34.20	100.00
Net/kg ($)	2.35 [e]	7.85 [f]	7.10 [g]	2.00 [h]	11.80 [i]	31.10

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

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

because they do not receive payment from fishers for use of capital equipment and their fixed and variable costs are higher. The lower net final value in Australia is attributed to higher transport and holding costs.

Fish Mortality and Transshipment Costs

Fish mortality was not factored into the costs of transportation or the distribution of wealth among stakeholders (Tables 2.3 and 2.4). Mortality remains a major factor, however, in the cost of delivering LRFF to markets in Hong Kong, China. Most fish deaths occur during the holding phase in the source country and during the transhipment phase.

The use of sea transport to deliver LRFF to markets usually requires the fish be held after capture in floating cages for up to one month and sometimes longer. Mortality during the holding phase has been estimated to average as high as 50% between reef and retail, with estimates of up to 30% during the first 3–5 days of captivity. During these early phases, mortality is often the result of cyanide use but has also been attributed to poor cage conditions, overstocking of cages, poor handling and feeding practices, and the spread of disease.[56] As noted above, subsequent mortality is much lower when fish are freighted by air; mortality rates when using air transport bins are reported to average less than 5%.[57]

Mortality, particularly with sea transportation, is usually factored into the buying price at the import destination and is dictated by the condition of the fish, distance to market, and the supplier's history. Another factor that dictates buying price is weight lost by the fish during transit, which can be as much as 15%.[58]

MACROECONOMIC ISSUES

Macroeconomic issues affect the LRFF trade in both importing and exporting countries. In Hong Kong, China, the CPI fell from 106.9 in December 1997 to 93.8 by December 2002

[56] Sadovy and Vincent 2002.
[57] L. Peterson, personal communication.
[58] Patrick Chan, personal communication.

(October 1999 = 100). During this period of deflation, wholesale and retail prices of all LRFF species fell far below earlier reported high prices,[59] with wholesale and retail prices for high-value species (humpback grouper, humphead wrasse, and leopard coralgrouper) being 35–45% lower in 2002 than in 1997.

The impact of these price declines, however, has been mitigated in source countries by favorable exchange rate fluctuations, as the US dollar strengthened against other currencies,[60] cushioning the prices received by suppliers. In Australia, the wholesale price of leopard coralgrouper in November 1999 was HK$300/kg—a domestic price of A$60.50/kg (A$1 = HK$4.95). By November 2000, the wholesale price of coralgrouper had fallen to HK$252/kg but the falling Australian dollar (A$1 = HK$4.07) meant that the domestic price equivalent rose to A$61.80/kg. By November 2001, a slightly higher HK price for live coralgrouper of HK$262/kg and a static dollar (A$1 = HK$4.06), meant a domestic price equivalent to A$64.60 for coralgrouper.[61] In Southeast Asia, most currencies have likewise been heavily discounted,[62] resulting in an increasing beach price paid by dealers and traders.[63] While a weaker currency improves the return from fishing, export-oriented fisheries, such as for LRFF, respond logically to such trends by intensifying effort and impact on fish populations.

Hong Kong, China remains the major destination for consumption of LRFF and, despite declining import volumes and depressed prices, will likely continue this dominance for some years yet. Of growing concern is the expanding market associated with increased incomes in mainland PRC, which is placing increased pressure on LRFF populations.

Value adding to existing catches remains one of the key attractions of the LRFF trade in most source countries. While complex business relationships tend to obscure the real distribution of value among market participants, returns from LRFF fisheries evidently remain profitable in many countries.

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[59] Reported by Lau and Parry-Jones (1999).

[60] The Hong Kong, China dollar is pegged against the US dollar at a rate of HK$7.80 = US$1.00

[61] G. Muldoon, unpublished data.

[62] By 2002, the Indonesian Rupiah and Philippine Peso had depreciated by 70% and 40%, respectively, since 1997.

[63] Erdmann and Pet-Soede 1999; Padilla et al. 2002.

3 THE FISH RESOURCES

FISH SPECIES IN THE TRADE

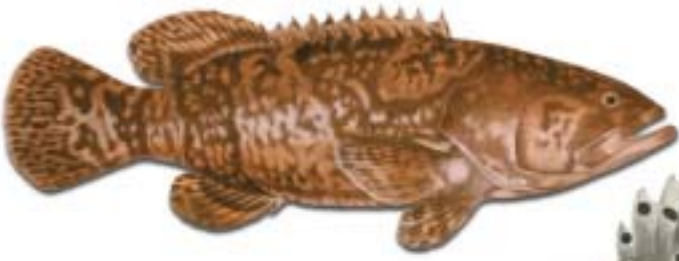
The preferred kinds of fish in the LRFF trade come from several families. The bulk of the trade consists of the groupers (Serranidae). Also taken are snappers (Lutjanidae), wrasses (Labridae), small numbers of emperors (Lethrinidae), sweetlips (Haemulidae), seabream (Sparidae), and members of a few other families. Highest in unit value are the humpback grouper, the humphead wrasse, and the leopard coralgrouper, followed by the squaretail coralgrouper, brown-marbled grouper, and camouflage grouper. The common groupers of lower value ("other grouper") are more preferred for home consumption. These fish, together with their species names, are shown in Table 3.1 and Plate 7 below.

For the purposes of this book, standard names of the Food and Agriculture Organization of the United Nations (FAO) have been adopted. Common English names used by AFCD and CSD in Hong Kong, China are given in parentheses in Table 3.1.

The most common groupers in the trade, by weight, are the brown-marbled grouper, camouflage grouper, leopard coralgrouper, orange-spotted grouper, and Malabar grouper.

Table 3.1: The Principal Species in the Live Reef Food Fish Trade

FAO (Hong Kong, China) Name	Scientific Name	Trade Status
Giant (giant) grouper	*Epinephelus lanceolatus*	High value
Humpback (highfin) grouper	*Cromileptes altivelis*	High value
Humphead (Napoleon) wrasse	*Cheilinus undulatus*	High value
Leopard (leopard) coralgrouper	*Plectropomus leopardus*	High value
Spotted (spotted) coralgrouper	*Plectropomus maculatus*	High value
Squaretail (squaretail) coralgrouper	*Plectropomus areolatus*	Medium value
Brown-marbled (tiger) grouper	*Epinephelus fuscoguttatus*	Other grouper
Camouflage (flowery) grouper	*Epinephelus polyphekadion*	Other grouper
Duskytail (duskytail) grouper	*Epinephelus bleekeri*	Other grouper
Greasy (greasy) grouper	*Epinephelus tauvina*	Other grouper
Hong Kong (red) grouper	*Epinephelus akaara*	Other grouper
Malabar (Malabar) grouper	*Epinephelus malabaricus*	Other grouper
Orange-spotted (green) grouper	*Epinephelus coioides*	Other grouper



Giant grouper*

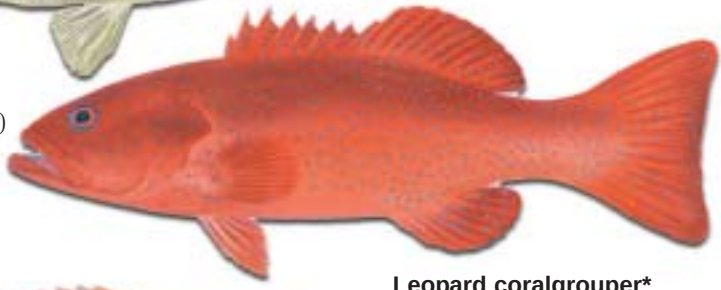
Epinephelus lanceolatus (Bloch, 1790)

Humpback grouper*

Cromileptes altivelis (Valenciennes, 1828)

Humphead wrasse*

Cheilinus undulatus (Rüppell, 1835)



Leopard coralgrouper*

Plectropomus leopardus (Lacepède, 1802)

Spotted coralgrouper**

Plectropomus maculatus (Bloch, 1790)

Squaretail coralgrouper*

Plectropomus areolatus (Rüppell, 1830)

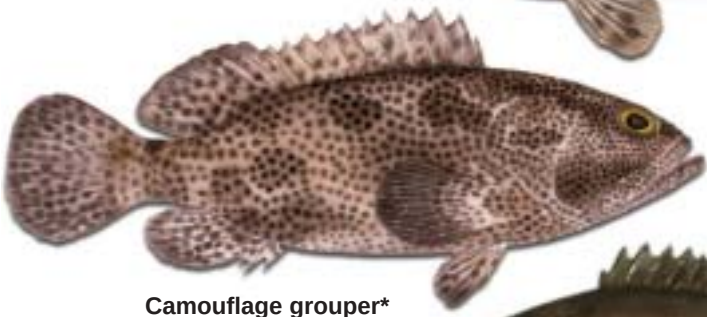
* *Illustration by Les Hata. Copyright: Secretariat of the Pacific Community*

** *Used with permission of CSIRO. Copyright: CSIRO Marine Research*

Plate 7. Principal Species in the Live Reef Food Fish Trade

Brown-marbled grouper*

Epinephelus fuscoguttatus (Forsskål, 1775)



Camouflage grouper*

Epinephelus polyphekadion (Bleeker, 1849)

Duskytail grouper**

Epinephelus bleekeri (Vaillant, 1878)

Hong Kong grouper***

Epinephelus akaara (Temminck & Schlegel, 1842)

Malabar grouper***

Epinephelus malabaricus (Bloch & Schneider, 1801)

Orange-spotted grouper***

Epinephelus coioides (Hamilton, 1822)

* *Illustration by Les Hata. Copyright: Secretariat of the Pacific Community*

** *Used with permission of CSIRO. Copyright: CSIRO Marine Research*

*** *Used with permission of John E. Randall*

BIOLOGICAL CHARACTERISTICS OF TARGET SPECIES

The fish preferred for the LRFF trade, mainly groupers, are typically carnivores/predators at the top of their food chain and many exhibit aspects of reproductive biology that make them particularly vulnerable to fishing. Fish at the top of the food chain have several characteristics of interest from the fishery viewpoint:

- when fully grown, they have virtually no predators other than humans;
- they are not common (i.e., have low abundance), relative to the animals at lower levels of the food chain, on which they feed;
- most are long lived, often attaining several decades; and
- they mature relatively late in life.

These characteristics have clear implications for the LRFF trade. First, it takes many years to replace an adult grouper taken from a reef. Second, given the market's general preference for relatively small fish, many immature or juvenile individuals are taken. For example, size data collected from retail markets over a 3-month period in Hong Kong, China of valuable and common species in the trade showed that among the larger species, some 70% of humphead wrasse, 80% of brown-marbled groupers, and almost all giant groupers on sale were juveniles. Of the more commonly traded smaller species, such as orange-spotted grouper, camouflage grouper, and leopard coralgrouper, most fish on sale had attained adult size.[64] Third, the potential productivity, or potential yield, of target species is low compared to that of fish lower in the food chain. Severe overfishing (see Box 3.1) can reduce this productivity if reproductive output declines at low population levels (known as depensation).

Another feature of these fish is that some are produced by grow-out, with two important biological implications for wild fish populations. The first is that grow-out involves a significant number of fish taken from the wild and grown in captivity, thereby removing fish that potentially would replenish adult populations.

[64] Lee and Sadovy 1998; Sadovy and Vincent 2002.

Box 3.1: Overfishing

The term *overfishing*, as used in this book, refers to biological overfishing: a state whereby too many fish are removed too quickly to allow for maximum yield or population recovery and that can ultimately lead to excessive population depletions and extirpations. Overfishing can be classified as growth overfishing, whereby fish are removed at too small a size to maximize yield; recruitment overfishing, whereby too many spawners are removed, resulting in reductions in recruitment and productivity; and ecosystem overfishing, whereby selected species within the ecosystem are being removed with adverse consequences on reef assemblages. If overfishing reduces populations to a point at which depensatory factors start to affect reproductive potential, e.g., reproduction is compromised at low population sizes perhaps because individuals cannot find mates (a density-dependent effect); then the long-term productivity of the stock may become compromised—fish numbers get too low for effective reproduction to occur.[65]

The second is that they need large amounts of feed in order to attain saleable size (as do, for that matter, market-sized fish that are held for substantial periods of time before being sold). And because they are carnivorous, the feed is usually other fish that are also taken from the wild (see Chapter 6). Such "fish feed" involves not only large volumes of fish but can sometimes include the young of fish that would otherwise, once grown, be used for human consumption.[66] From the viewpoint of sustainability, such considerations need to be taken into account.

Reproductive Behavior

Other relevant features of many LRFF species are that they aggregate periodically in large numbers to spawn, and that they change sex as they grow. Aggregation behavior (see Box 3.2) makes the fish very vulnerable to a fishery, because the aggregating areas are often well known and the high density of fish allows many fish to be caught with little effort. Indeed,

[65] Hutchings 2000.
[66] Chau 2004.

aggregations have become desired targets in the LRFF fishery. Given the relatively scarce nature of these top predators, the capture of large numbers of reproductive fish, as would be required for an export market, almost certainly has implications for the survival of their populations over a wide area. The problems associated with aggregation-based exploitation are well documented.[67]

Box 3.2: Spawning aggregations

Many reef fishes aggregate consistently every year at specific times and places to reproduce (spawn). Reef fish spawning aggregations can vary from gatherings of a few hundred fish to concentrations of tens of thousands. Many species exploited for the LRFF trade aggregate in hundreds or thousands and heavy fishing targeted on such gatherings can remove a significant proportion of assembled fish within a few days. Spawning aggregations typically occur in the same locations and at the same times each year, usually according to specific moon phases, and hence are highly predictable. Aggregation sites are often on the outer reef slopes, in reef channels or at drop-offs or promontories, and form for just a few weeks (often spread over several lunar cycles) each year. While they are known to be able to support low levels of subsistence fishing in the long term, they are not able to withstand heavy fishing of the type likely to be necessary for export markets.

Changing sex is fairly common among reef fishes and implies that different-sized fish have different sex ratios, ranging up to 100% of either sex at the extremes. Groupers are generally females when small and males when large. A size-selective fishery for groupers, such as the LRFF fishery that targets relatively small individuals for market or grow-out, could potentially reduce the number of females in a population to the extent that reproductive output (number of eggs) declines. The resulting "protection" afforded the large males is fortuitous. But, of course, if there are no eggs to fertilize …

[67] For supporting and background information and materials see www.scrfa.org, the website of the Society for the Conservation of Reef Fish Aggregations.

Vulnerable Species

Several species in the trade are threatened by fishing and careful consideration is needed in determining whether to allow their exploitation and export. The humphead wrasse is classified as *vulnerable* in the World Conservation Union (IUCN) Red List[68] and was recently proposed for an Appendix II CITES listing, meaning that trade among party countries would be allowed but only with documentation. The humphead wrasse currently cannot be hatchery-produced.[69] The giant grouper is also considered to be threatened. Although this species is being successfully reared in hatcheries in Taipei,China, elsewhere, small numbers of large individuals taken from the wild continue to enter the live fish trade. The humpback grouper is also thought to be at risk in many areas and this species can be hatchery raised.

TARGET FISH PRODUCTIVITY

Answering one of the most basic questions of the LRFF trade—how many fish can be harvested sustainably, i.e., without excessively depleting the exploited populations—is very difficult. In this section, observed yields of reef fish, and groupers in particular, especially those sought in the LRFF trade, are reviewed in order to give a rough idea of the potential productivity of LRFF resources. Estimates of potential yield are compared with recent estimates of actual LRFF regional production, with the aim of assessing whether or not and to what degree the region's LRFF resources are being overfished.

Observed Reef Fishery Yields

Although actual, observed yields (defined in Box 3.3) of fish from coral reefs do not necessarily represent levels that are sustainable, optimal, or even advisable, they do give a useful

[68] The Red List is a listing of the conservation status of plants and animals and indicates those assessed to be threatened with extinction.

[69] Sadovy et al., in press. One objective under Appendix II of CITES is to collect more data and monitor trade of listed species. Relevant countries are also encouraged to introduce protective legislation.

indication of the range of possible yields. Yield is a function of many factors: current and historical levels of fishing effort, the reef community targeted, and the type and condition of the reef habitat. Estimates of reef finfish yield also depend on how they are calculated, such as which species are considered "reef species" and which substrate types and depth ranges are considered "reef."

Such factors mean that comparisons of reported yields among different reef areas and studies must be made with caution, but the range of findings is, at least, illustrative. One study[70] showed total reef fishery (fishes and invertebrates) production of 3–18 t per km^2 per year for reefs ranging in health from poor to excellent. Another review of yields for various reefs[71] gave a range of 0.1– 44.0 t per km^2 per year. From these and other reviews[72] it is reasonable to conclude that, while yields of all reef-associated resources combined can exceed 5 t per km^2 per year, those much in excess of 15 t per km^2 per year are likely to be rare.

Box 3.3: Fisheries yield

Yield is defined as catch per unit area per unit time; here, it is expressed in terms of tonnes per square kilometer per year.

Potential Grouper Yields

Based on the above review, 5 t per km^2 per year could be considered a reasonably attainable sustainable reef finfish yield for a typical reef (i.e., a reef in moderate condition). In one review of reef fish yields in the region, groupers were found to make up between 3 and 18% of total reef fish catches.[73] Ten percent is probably a reasonable estimate of the average contribution of groupers to reef fish catches. Taking the "reasonably attainable reef fish yield" of 5 t per km^2 per year and the estimate that groupers typically comprise 10% of total reef fish yield, then 0.5 t per km^2 per year would represent a reasonably attainable grouper yield for reefs in moderate condition. Expected yields of LRFF

[70] McAllister 1988.
[71] Dalzell 1996.
[72] Russ 1991; McClanahan 1995; Jennings and Polunin 1995.
[73] Dalzell et al. 1996.

grouper species would be less than this because only some of the available grouper species in any one location are targeted for the live trade. For the purpose of illustration, it is assumed that the potential yield of LRFF groupers is 80% of that for all groupers, giving a reasonably attainable LRFF grouper yield of 0.4 t per km^2 per year. It is emphasized that these potential yield estimates are, of course, very rough, and they are used here only for the purpose of giving an indication of the capacity of the region's reef resources to support LRFF fisheries and the broader LRFF trade.

This estimate of potential LRFF yield (or more specifically, of "reasonably attainable LRFF grouper yield") is now compared with recent estimates of actual grouper production in the Indo-Pacific region, as determined by a combination of FAO fishery production figures and independent estimates of LRFF trade volumes.

ANNUAL GROUPER PRODUCTION

Total annual grouper production in the Indo-Pacific can be roughly estimated by looking at the various fisheries that harvest groupers, including those for live fish—both for market-size individuals and small individuals for subsequent grow-out—and the fisheries for non-live product, including both subsistence and commercial fisheries.

Grouper Live-fish Fishery Production: Market-size Fish

The amount of fish caught for the LRFF trade far exceeds the quantities discussed in Chapter 2, which relate only to imports into Hong Kong, China. In addition to the official import estimates are informal estimates of imports from transport vessels licensed in Hong Kong, China, exempted from officially reporting their imports. Moreover, these imports are only about 60% of the international trade, virtually all of which is based on fish from Indo-Pacific reefs.[74] Of the total fish entering the trade, the proportion that is caught and marketed directly, i.e., not derived from one or other form of aquaculture (see Table 1.2), probably

[74] Johannes and Riepen 1995. Recently, interest in sourcing LRFF in Mexico has been expressed by Asian companies. Author's (YS) observation.

averages about 60%. Also to be taken into account are the mortalities incurred between capture and market, roughly estimated to be about 50%.[75] Incorporating these factors into annual estimates of total production of wild-caught market-size LRFF groupers in the region gives an amount of 21,000 t in 2001.

Grouper Grow-out Aquaculture Production

According to FAO and supplementary data on aquaculture in the region (see Chapter 6), cultured grouper production totaled about 25,000 t in 2001. To determine the portion of this total that was grown-out wild-caught fish, the proportion of fish from full-cycle (i.e. hatchery) aquaculture (15%) is deducted. On this basis, regional production of cultured wild-caught groupers in 2001 was about 16,000 t. Further, if 50% pre-market mortality for these fish is assumed, then the grow-out production is equivalent to reef production of some 32,000 t/year.

Total Regional Live Grouper Production

Total wild-caught live grouper "production" (including all those fish that do not survive between capture and market) in trade and culture was, by summation of the fishery and wild-caught culture components, an estimated 53,000 t in 2001.

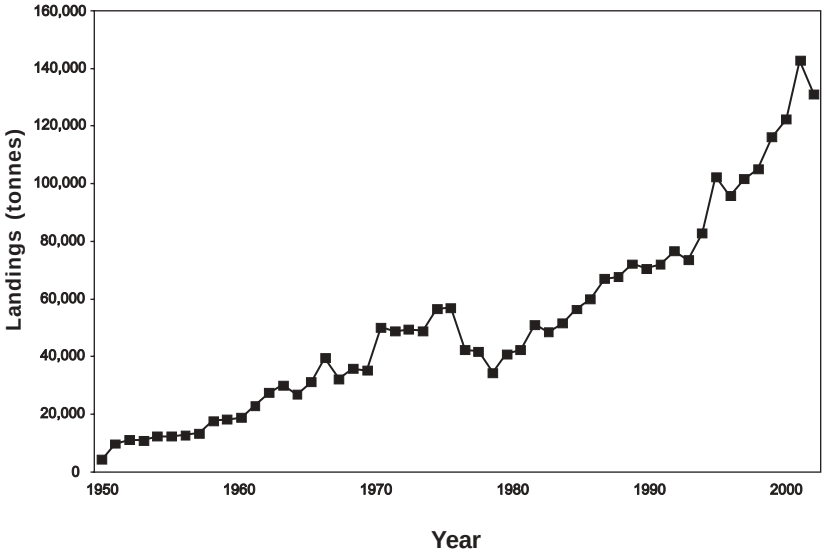
Subsistence and Commercial (non-live) Grouper Capture Fisheries

The target fish species of the LRFF trade are also caught in numerous small-scale subsistence and commercial fisheries around the region. Annual catches of all groupers in these fisheries, as reported to FAO since 1950, are presented in Figure 3.1. The total landings reported to FAO, which reached 131,000 t in 2001, probably underestimate actual landings, given that the remoteness of many areas, underreporting, and the subsistence nature of many reef fisheries make accurate reporting difficult. The proportion of the total made up by species that are desirable for the LRFF trade was estimated above at about 80%, i.e., about 100,000 t.

[75] Sadovy and Vincent 2002.

The major grouper fishing nations and their landings in 2001 were Indonesia (52,000 t), PRC (45,000 t), Pakistan (16,000 t), Philippines (13,000 t), and Malaysia (10,000 t).[76] The trend in all these countries except the Philippines has been one of increasing reported landings since the 1980s (PRC began reporting only in 1990). Philippines reported landings have declined gradually from a peak of 28,000 t in the mid-1980s. It is assumed that the vast majority of landings reported to FAO are dead rather than live fish. Problems of underreporting, overreporting, and irregular reporting are chronic issues in catch statistics. Thus, the data in Figure 3.1 must be treated with caution.[77]

Figure 3.1: Annual Reported Landings of Groupers in the Indo-Pacific Region, 1950–2001



Source: FAO Fishery Information Data and Statistics Unit 2003.

[76] The United Arab Emirates reported grouper production of about 21,000 t in 2001. However, observers suggest that this is probably aberrant and that production was much the same as in recent years at about 7,000 t. The latter figure is used in Figure 3.1.

[77] A pertinent issue is to what extent live grouper "landings" appear in fisheries catch data. In the Philippines, as a significant case, live grouper exports are recorded by the national statistical office (if the exporting companies provide this information), while grow-out and full-cycle aquaculture groupers (whether for domestic consumption or export) are recorded by the fisheries statistics system, separately to the catch of (dead) wild groupers. Thus, LRFF trade fish are a proportion of the aquaculture, rather than landings, statistics.

Total Regional Grouper Production

In estimating the total production of groupers from all sources—LRFF capture and culture, plus the non-live-fish fisheries—it is assumed that LRFF capture fisheries data are typically not included in the FAO fisheries data in Figure 3.1, but that LRFF culture operations are covered in the FAO aquaculture data. On this assumption, total grouper production in the region in 2001 was about 184,000 t.

Based on a total reef area for the Indo-Pacific of 284,300 km^2,[78] and estimated production from all wild-caught sources in 2001 of 184,000 t, the actual average total grouper yield was more than 0.6 t per km^2 per year, of which the LRFF grouper yield was about 0.5 t per km^2 per year with landings increasing rapidly (Fig. 3.1). The part of this yield taken by the LRFF trade was equivalent to 0.2 t per km^2.

Overall, although average regional grouper yields give the impression of approximating a sustainable level, at the more realistic local level, they are clearly not. At any one time, the bulk of the fish in the live fish trade comes from a small proportion of the region's total reef area, mainly Southeast Asia.[79] The reef area in Southeast Asia is estimated at 91,700 km^2, and the average grouper yield there is currently at a level closer to 2 t per km^2, well beyond what is likely to be sustainable. The Philippines is a case in point; yet only in that country has a decline in reported grouper landings occurred (whether from general fishing pressure or the Philippines' long association with the LRFF trade is unclear).

Another important pattern of LRFF fishing operations that is readily apparent is a tendency to shift among areas, operating in a given area for a few years and then moving on (as implied in Figure 1.2). This pattern is typically associated with "slash-and-burn" types of activities, in which intensive fishing removes the readily available fish and then moves on, without being accountable for the resulting overfished state of targeted stocks. Worse than this, there are many reports[80] stating that the fishery leaves behind not only depleted fish populations, but also

[78] Spalding et al. 2001.
[79] Bryant et al. 1998.
[80] See Johannes and Riepen 1995; Barber and Pratt 1997; Erdman and Pet-Soede 1998; Bentley 1999.

damaged or dead reef. This pattern is strongly indicative of unsustainable fisheries.

LONG-TERM EFFECTS OF LRFF FISHERIES

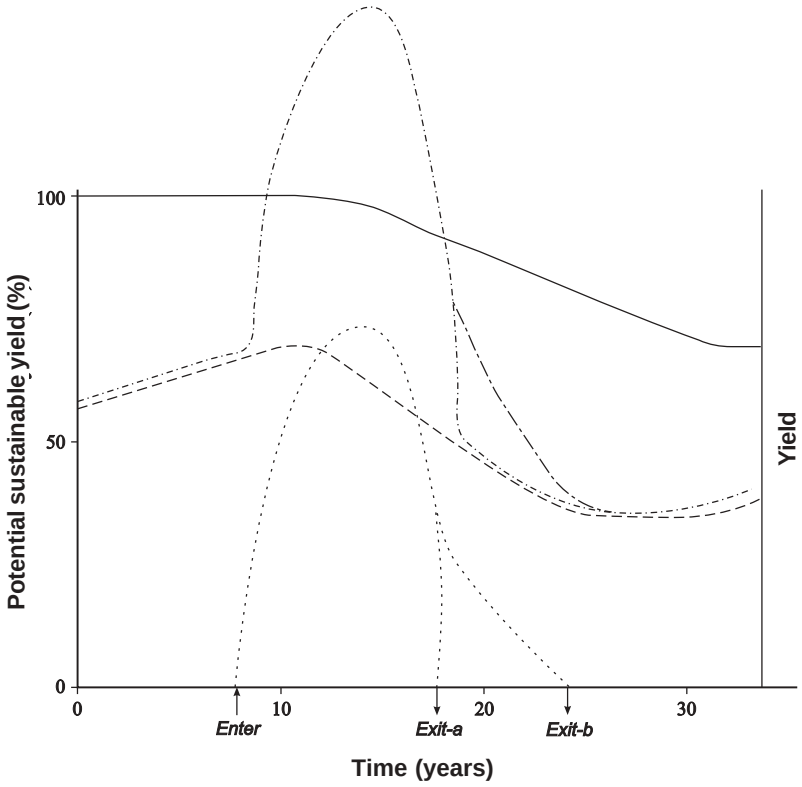
If one accepts the analogy of slash-and-burn agriculture, then the consequences of the lack of a fallow period—a period of several years to allow regrowth and recovery of the natural resources—for coral reefs must be explored. The nature of LRFF fishing operations implies not only depletion of grouper resources but also loss of potential for their recovery in even the medium term, as shown in Figure 3.2. The negative effect of an LRFF fishery may be a decadal phenomenon.

Ecosystem Considerations

In examining the full impact of overfishing, it is essential to consider the wider ecosystem effects of fishing, as well as that on target species. Beyond the loss of yield by direct removal of these top predators, is the cascading effect of their loss on both target and nontarget species in the reef ecosystem.[81] The least disturbance to the reef would occur if other (non-LRFF) groupers replace them, although the loss of any grouper species is to be avoided both to maintain biodiversity and because the role of individual grouper species on reefs is not known. However, as the groupers become rare, subsistence and other fishers, including perhaps LRFF fishers, would turn their attention to other top predators and then to fish in the next level of the food chain—smaller predatory fish including small groupers as well as a wide group of other species of omnivorous and herbivorous species at lower trophic levels. Because their food source becomes reduced by fishers, the top predators may not be able to return to their former abundance. This situation is called “fishing down the food chain” that is recognized to have occurred worldwide—big fishes of most kinds have almost disappeared from the world’s oceans.[82]

[81] Ruttenberg 2001; Dalzell 1996; Jennings et al. 1999.
[82] Myers and Worm 2003; Pauly and Maclean 2003.

Figure 3.2: Long-term Effects of LRFF



The drawing depicts a local reef fish fishery for species targeted by the LRFF trade before the LRFF fishery enters the local area, during its operations, and the likely long-term consequences to potential sustainable yield after the LRFF fishery has moved on. Its form results from a combination of interviews of fishers in the Philippines and general fishery theory, although the time scale of the x-axis is only approximate and the exact shapes of the three curves are unknown. Note that the left-hand axis refers to the solid line (potential sustainable yield) only; the other lines represent yields (right-hand axis).

Subsistence/commercial chilled reef fish fisheries (dashed line) have been taking an increasing proportion of total potential sustainable yield (solid line) due to the growing human population and cash economy.

When an LRFF fishery (dotted line) enters an area, there is a rapid increase in removal of target fish species because of the high interest by fishers in participating in the trade (including immigrant fishers attracted to the area) or because of promotion by government in the name of fisheries development. Also, most LRFF operations tend to be well organized and need substantial catches to be viable. As the combined live fish and subsistence/commercial chilled fisheries come to exceed the potential sustainable yield (dot-dash line) (e.g., with symptoms of declining catches, smaller fish sizes, loss of spawning aggregations, and fishers having to move further and further from home ports to maintain catches), production begins to decline.

When production of live target fish becomes too reduced, businesses are likely to move to another area (Exit-a), as indicated by the historic spread of the trade (see Figure 1.2). In some cases, the remaining sub-market size fish are taken and are grown to market size in captivity; in such cases, the LRFF trade operations may take longer to move on (Exit-b). The remaining fish population is likely to have been reduced in potential yield (solid line), at least in the medium term, because of reduction of spawning population (adults) and possible depensatory effects, elimination of spawning aggregations, and damage to habitat, especially if subsistence fishing continues. In the long term, recovery is possible, but, given the slow speed of recovery of target species and also of reef systems, is likely to take decades.

It is particularly worrying that in some areas where market-size fish have become depleted, such as in parts of the Philippines, Indonesia, and eastern Malaysia,[83] fishers turn to catching juveniles of target species for grow-out, further reducing spawning potential and placing additional pressure on other reef resources due to the need for fish feed.[84]

[83] Y.J. Sadovy, unpublished data; Daw 2002.
[84] Y.J. Sadovy, unpublished data.

A recent study has found that virtually wherever commercial-level or industrial fisheries have developed, the biomass (the total amount present at any one time) of fish populations has typically been reduced to 20% of pre-fishing levels within 15 years, and that the biomass of large predatory fish in nearly all industrially fished systems is now only about 10% of pre-industrial levels.[85] LRFF fisheries on reef ecosystems are no exception; they appear to operating at an intensity that has the same effect, which, if left unchecked, will be to the great detriment of human communities relying on the reefs for food fish. Furthermore, as implied above, after the most favored fish are decimated, fish further down the food chain may be taken in the quest for adequate supplies of live fish acceptable to consumers.

IMPLICATIONS FOR MANAGEMENT

This review of potential and actual LRFF production in the Indo-Pacific region makes it clear that LRFF fisheries often operate at intensities greater than the resources can support on a sustainable basis. In the region as a whole, LRFF production alone—without accounting for any other uses, such as fisheries for local consumption—appears to be close to our best approximation of a "reasonably attainable" level of sustainable production, while at a local, and probably more realistic level, capture rates appear to exceed by 3–4 times or more what are likely to be sustainable levels.

Clearly, there is a need to devise better ways of keeping LRFF harvest rates in accord with the limited biological productivity of the target populations. Achieving success there would not only help preserve the productive capacity of the region's grouper resources, but it would greatly reduce the risk of adverse ecosystem-level impact, which tends to follow in the wake of severe overfishing of target populations. A second important challenge is reducing the degradation of coral reef habitat caused by LRFF fisheries, particularly by the use of cyanide. In Chapter 5 is a review of the various approaches that might be used to satisfy these two critical management needs (and satisfy the broader economic and social objectives of resource management).

[85] Myers and Worm 2003

As with all fisheries, our management abilities are limited by the information on hand. With respect to the biological attributes of LRFF resources—that is, tropical shallow-water groupers and a few other species—the essentials are known: their potential productivity is relatively modest, so expectations of fishery production must be accordingly modest; certain species are so rare, unproductive, or valuable outside the LRFF trade that it does not make sense to export them at all; and many target species periodically gather in large aggregations to spawn, during which times they are especially susceptible to fishing. There is, of course, much more knowledge that would be valuable to have, but enough is known to improve greatly the way LRFF fisheries and the broader LRFF trade are managed.

Perhaps the greatest biological information need for LRFF fisheries is locale-specific information about the size and potential productivity of the target populations. This would greatly assist in determining whether a LRFF fishery, combined with existing subsistence use, would be viable at all, and if so, how best to control it. Monitoring the status of target populations over time would also be valuable. Although rigorous quantitative methods for obtaining these kinds of information are available, they are often cost prohibitive. However, there are many management options that do not depend on such information. Some[86] argue in favor of "data-less" management approaches for marine fisheries, citing as examples the little information that would be needed in order to protect tropical groupers from fishing during their highly predictable spawning aggregation periods, and to protect threatened species. These and other management approaches are more fully addressed in Chapter 5.

[86] e.g., Johannes 1998.

4 SOCIAL ISSUES

The "promise" of the LRFF trade has rarely been fulfilled for fishing communities in the region. Rather, the spread of the LRFF trade has more often than not resulted in a range of adverse impact. This chapter outlines some of the key social issues and impact resulting from the trade. First, examples of the general nature and evolution of the trade in the region are given, highlighting some of the social ramifications that have been experienced, both in the fisheries and in aquaculture operations. This is followed by a summary of some of the motivations for involvement in the LRFF trade and the direct impact on fishers and fishing communities.

EVOLUTION AND NATURE OF THE TRADE

The way that the LRFF trade has spread and its interaction with fishing communities has evolved over the life of the trade and varies somewhat between regions. The following section outlines examples from Southeast Asia and the Pacific, illustrating the range of social issues involved.

Indonesia: Kei Archipelago in Southeast Maluku District

Much has been published on the LRFF trade in Indonesia and while most articles focus on the resource, habitat, and fisheries components, many of those publications also include associated social issues.[87] What emerges from these and other publications is that the LRFF trade in Indonesia (and other areas of Southeast Asia) typically follows a similar progression.

The first phase involves the incursion of large foreign-owned or joint venture purpose-built LRFF catcher vessels with outside (nonIndonesian) fishers, using cyanide. These operations

[87] e.g., Johannes and Riepen 1995; Erdmann and Pet-Soede 1996; Jacques 1997; Barber and Pratt 1997, 1998; Thorburn 2001, 2003.

have relatively high overheads. Thus, they target the highest value fish and require large volumes of fish to be profitable. The high fishing pressure and the systematic use of cyanide to remove the target species result in significant overfishing of the target fish and damage to the reefs. As populations of the highest value fish dwindle, the vessels move on to new areas.

With the departure of the more capital-intensive operators, the second phase has usually involved small- to medium-scale operators, frequently businesspersons operating locally taking over. Characteristically, their approach has been to provide credit to local fishers to purchase boats and equipment, accepting live fish as payment, and requiring the indebted fishers to use cyanide supplied by the trader. At times, a trader will enter into a contract with a whole village for permission to develop an LRFF operation in their waters.[88]

The impact and implications, both social and ecological, of these phases have been described for the Kei islands in Southeast Maluku District, Indonesia.[89] With the arrival of the trade, conflicts soon developed between local fishers and the "foreign" fishing operations. These conflicts were in part over the perceived damage to the reefs from the use of cyanide, but of possibly greater significance was the villagers' perception that the LRFF operators were violating local access rights. Coercion and corruption have been key issues in the Kei islands LRFF trade, and similar instances have been recorded for other areas in Indonesia.[90]

In the second phase, conflicts and tensions still existed in Kei, but were focused more within the communities—fisher against fisher, family against family—over rights to fish areas and over the methods used. With the departure of outside companies, local businesspersons took advantage of these divisions and entered into agreements with the leadership to continue LRFF operations. The circumstance also encouraged the continued use of cyanide. These businesspersons had approached the community appropriately, asked permission to fish on local waters, and paid a fee. While within the community there remained a division between pro- and anti-cyaniding groups, a loan from two

[88] Thorburn 2001, 2003.
[89] Adhuri 1998; Thorburn 2001, 2003.
[90] Barber and Cruz 1998; Lowe 1999, 2002.

fish traders to the village to build a new mosque resulted in considerable support for the continuation of the LRFF trade.

The conflict between the early LRFF companies and local communities in Kei was caused not only by the companies using cyanide, but also, and more importantly, by the companies' lack of understanding of local customary tenure. In the second phase, the operators were able to exploit local conflicts and community social needs.

The Pacific

While the expansion of the LRFF trade into the Pacific since the mid-1980s has shown some of the characteristics of the progression mentioned above, the particular circumstances in the Pacific have resulted in a slightly different set of social issues. In part, this is because of the extreme distances from the market in Hong Kong, China; the remoteness and relative small areas of reefs; an apparent lower density of groupers on Pacific island reefs; and a difference in attitude toward commercial and subsistence fisheries (where commercial fishing is largely a sporadic activity often related to specific financial needs such as school fees).

Papua New Guinea

LRFF operators have been operating in PNG since at least 1991, when an operation was established in the Hermit Islands. As one observer[91] wrote:

> *The effects of live reef fish export fishing operations on the social life of villagers in coastal areas promises to be at least as destructive as that caused by the taking of baitfish by foreign tuna fishing companies in the late 1970s and early 1980s. Jealousy over payments to fishermen and arguments over the fate of inshore fish resources leading to physical confrontation between clans and sub-clans, has*

[91] Richards 1993, p.11.

already developed in the Hermit Islands of Manus Province and in the Tsoi Islands of the New Ireland Province. There has reportedly been physical confrontation between Hula villagers and live reef fish buyers over fish prices. Provincial leaders in the New Guinea Islands region should already be aware of the social cost of allowing foreign fishing vessels and fishermen to operate in inshore areas, despite the "joint venture" nature of the arrangements.

The Hermit Islands operation lasted only two years and ended as a result of community concerns over fishing impact. Since then LRFF operations have occurred in Milne Bay, Bougainville, New Ireland, and East New Britain provinces. A joint venture between a Hong Kong, China firm and a company incorporated by the local youth council in Milne Bay began fishing in 1997 as a youth training partnership. The aim was to train local fishers in hook-and-line live capture techniques. Instead, the operation trained 40 fishers to use cyanide to catch fish.[92]

Despite these largely unsuccessful operations and the social problems they caused, there is still keen interest from a number of communities within PNG to develop LRFF operations in their areas with outside partners. There is still an entrenched belief that the LRFF trade will be profitable for island communities (or at least provide some income generation in areas where opportunities are very limited) and worth the impact.

Solomon Islands

The first recorded LRFF operation in the Solomon Islands was in 1994 in Marovo Lagoon, followed by operations in Roviana Lagoon, and Ontong Java. These fisheries targeted spawning aggregations, had very high post-capture/transportation fish mortalities, and paid quite low prices to the fishers. Disputes over the primary rights to spawning aggregations increased with the advent of the LRFF trade. There were also claims of misappropriation of funds from the operation that were intended

[92] Cruz and McCullough 1998.

for community use. Foreign companies, and especially those involved with the LRFF trade, do not always understand traditional marine tenure systems, and attempt to have government authorities sanction their activities, or alternatively have a vague understanding of tenure systems, but end up negotiating an agreement with the wrong villagers or clans.[93]

At a consultative workshop in 1999 on the LRFF trade, the community representatives indicated three issues of highest concern: the low prices paid by the company (prices were the same as, or only slightly above, the rates for dead fish); the wastage of fish, both bycatch and post-capture mortality (the fishery obtained a reputation for being wasteful of a food resources, especially in remote areas where the bycatch and dead target fish could not be fully used by the villages due to the large amounts and limited consumption and/or storage ability, or due to the distances of the fishing sites from the village); and concern over the targeting of spawning aggregation sites (especially related to ownership and use-rights disputes).[94]

While the impacts vary between the areas where the trade in the Solomon Islands has operated, there is some common impact:

> *"Fishers exerted extraordinary fishing effort during the LRFFT in all regions. This impacted significantly on the conduct of normal household and village duties. Many fishers established remote camps on islands in close proximity to spawning aggregation sites and would return to villages on weekends. ...Men dedicated all of their time to targeting spawning aggregations. Village and household duties, including the daily provision of fresh food, suffered as a result. The LRFFT, in the manner that it was conducted prior to the moratorium, was a shock event in the lives of villagers throughout the study areas."*[95]

[93] Johannes and Lam 1999.
[94] SI Fisheries 1999.
[95] Donnelly 2000, 2001; quotation from Donnelly 2001, p.93.

Australia

The development of the LRFF trade in Australia provides a contrast to the above examples. Prior to 1993, all the catch from the Great Barrier Reef commercial reef line fishery was sold as frozen or chilled fillets or whole fish. The first LRF exports were made in 1993, with a rapid increase from 1996 to the present. For the most part, the growth in the LRFF fishery involved a shift in holding and marketing practices of existing line fishers rather than new operators; the live export of these fish has presented a value-adding for the reef line fishery compared with the frozen trade.[96] This presented a strong incentive for fishers to enter the fishery and many dormant licenses were taken up as a result.

The target species and areas fished have also been the target species and the areas fished by the large recreational fishery, resulting in much controversy and conflict between the commercial and recreational fishing sectors.[97]

MOTIVATION FOR PARTICIPATION

Perceived Benefits

While individual motivations for entering into the LRFF trade vary from fisher to fisher and area to area, some of the main driving forces include the chance to realize higher prices for the fish they catch, limited alternative market opportunities, the need for money for specific occasions, and, in the case of the poor, the basic need for any income. For communities, the decision to participate in the LRFF trade is usually made by the leaders either to benefit the community (especially if a LRFF operator offers to provide materials or funds to undertake community projects), or to benefit themselves, or both. Unfortunately many of the decisions to participate are based on incorrect information, at times on deliberate misinformation, and/or on false promises as to potential prices and long-term benefits of the trade. In the Pacific, many operators have promised to train local fishers in appropriate hook-

[96] Mapstone et al. 2001.
[97] Mapstone et al. 2001.

and-line fishing techniques, but often continue to use foreign fishers.

What fishers most commonly hear about the LRFF trade are the high prices that have been obtained at retail. The highest prices occurred in the mid-1990s and many publications referenced the extremely high value of some species of live fish in the Hong Kong, China market.[98] It was not made clear at the fisher and community level that the prices quoted were frequently the restaurant retail prices. As explained in Chapter 2, the prices to fishers in recent times are usually closer to restaurant prices than in earlier years. However, the prices offered to fishers in some areas have been only slightly above what could be obtained by selling on the local fish markets.

The LRFF trade has provided an opportunity for remote communities and fishers to sell fish and obtain income. Because the fishery does not require refrigeration or ice, it is particularly suited to such areas. This is one of the key reasons, along with the opportunity to obtain foreign income, why governments have looked with hope to this fishery in the Pacific.

In some areas, such as some of the Pacific islands, the target species are not locally preferred food fish. In many parts of Micronesia, for example, groupers are considered a relatively low-value food fish (in subsistence terms) and considered "surplus" to local subsistence requirements. When an LRFF operator offers to purchase these fish, the fishers are usually willing to oblige.

Some Realities

As outlined in the case studies above, the perceived or promised benefits have rarely been obtained, or where they have been realized it has usually been with considerable opportunity and environmental costs. While fishers may gain an income in the short term, in many cases they end up indebted to brokers (especially in Southeast Asia), or required to fish in a way that is incompatible with local practices and habits.

The prices obtained by fishers have always been a major cause for disquiet and a prime factor in LRFF trade operator-fisher disputes. The operators will nearly always try to pay the lowest

[98] e.g., Johannes and Riepen 1995.

price possible to the fishers in order to maximize their own profit and to provide a buffer in view of the considerable risks involved with shipping live reef fish. Rarely are fishers aware of the risks involved, or understand the extreme volatility of the wholesale prices in Hong Kong, China. The fishers assume that the brokers and wholesalers are making exceptional profits at their costs. While that may have been the case in the 1980s and 1990s, it seems less so in the current market, where most of the profit appears to be at the restaurant/retailer stage.

The historically poor record of the industry as a whole, combined with the nature of the trade and the potential for quick profits for the operators themselves, means that the issue of corruption remains one of the main consequences of the trade. The industry has been responsible for corruption and coercion at all levels of operations, from fishers, community leaders, government fisheries and enforcement officers, and brokers to the operators.[99]

Socioeconomic Benefits of the Aquaculture Subsector

Unlike the LRFF capture fisheries, marine finfish aquaculture provides important socioeconomic benefits to coastal communities throughout the Asia-Pacific region. The development of "backyard" hatcheries in northern Bali, for example, has contributed substantially to the economic development of this region. One reason for the large-scale adoption of backyard hatcheries is the substantial increase in income that Indonesian farmers can obtain from fish culture compared with more traditional agricultural pursuits, such as coconut plantations.[100]

Grow-out of live reef fish is more accessible to poorer farmers than is hatchery production of these fish. Economic evaluations of grouper grow-out in the Philippines indicate investment payback periods of 1.2–1.7 years.[101] Grouper culture in the Philippines is more profitable than milkfish culture and requires less capital investment. It is, thus, more attractive to farmers.[102]

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[99] for examples, see Richards 1993; Johannes and Riepen 1995; Johannes 1997; Barber and Pratt 1997, 1998; Adhuri 1998; Bentley 1999; Erdmann 2001, 2002; Thorburn 2001, 2003; Lowe 2002.
[100] Siar et al. 2002.
[101] Baliao et al. 1998, 2000.
[102] Yap 2002.

IMPACT ON FISHERS AND COMMUNITIES

There has been a range of documented impacts on fishers and their communities as a result of participating in the LRFF trade. These impacts and issues can be considered under three broad, overlapping headings: health impact, societal issues, and socioeconomic concerns.[103]

Health Impact

The most significant impact on the health of fishers involved with LRFF operations has been diving related. LRFF operators in some areas employ divers operating with hookah air supplies (surface compressors) to capture fish by using cyanide to stun the fish, or to service traps placed to target groupers. It has been well documented that most divers involved with LRFF operations do not receive much training, if any. Often the equipment is very rudimentary, badly maintained, and used incorrectly. The primary health problems include paralysis or death from the "bends" (decompression sickness), resulting from remaining underwater for too long, rising to the surface too quickly, or making too many repeat deep dives.[104]

While good data are lacking, there are accounts of one Filipino community having 30 cases of the bends among 200 divers, with 10 deaths.[105] Several Filipino communities have at least several deaths each year plus many cripplings due to bends.[106] The mortality rate for cyanide divers in Indonesia is estimated to be 1% per year.[107] Many of the divers are unaware of the causes of the bends; some Indonesian divers attribute the condition to "ghosts of the sea."[108] In addition to the bends, many of these divers also become poisoned by consuming contaminated

[103] More detailed descriptions and/or summaries of the following issues and impact can be found in Richards 1993; Johannes and Riepen 1995; Erdmann and Pet-Soede 1996; Barber and Pratt 1997; Jacques 1997; Johannes 1997; Johannes and Djohani 1997; Adhuri 1998; Bentley 1999; SI Fisheries 1999; Donnelly, et al. 2000; Donnelly 2001; Thorburn 2001, 2003, among others.
[104] See Jacques (1997) for an account of trap fishers repeatedly bounce-diving to 27 meters depth in Indonesia.
[105] Barber and Pratt 1997.
[106] Information from a June 2003 survey in Busuanga, Philippines, by Yvonne Sadovy.
[107] Cesar 1996.
[108] Johannes and Riepen 1995.

air because of exhaust fumes being sucked into the air intake, improper use of lubricant oils, and poorly maintained or antiquated equipment.

Due to the high rate at which cyanide is metabolized in live fish, there does not appear to be any known effect on the end-consumer in the LRFF trade. However, fish that die from overdosing—both target fish and some of the bycatch—are often consumed by fishers' families or sold on the local markets. Cyanide tends to be concentrated more in the internal organs, which are often the preferred part of the fish for coastal people. Thus, there is a potential (not yet studied) health risk from the consumption of these fish. Cyanide-laced baits have reportedly been used in traps to sedate groupers and in hook-and-line fishing at spawning aggregations. Occasional deaths have been reported from eating fish with cyanide-laced baits still in their stomachs and some people were poisoned from eating fish transported in containers used to hold cyanide tablets.[109]

Societal Issues

A significant social impact on fishing communities of the LRFF trade in their areas involves disputes that develop over use rights and the benefits gained from the fishing operations. Use rights and boundary issues that may not be significant when fishing is largely subsistence in nature, can and do, erupt into major disputes between individuals, families, clans, or villages when the LRFF trade offers the opportunity of higher prices.

While some of these disputes relate to the destructive and wasteful methods used (e.g., cyaniding and targeting spawning aggregations), more often it is based on the uneven distribution of royalties and benefits, resulting in jealousy and a desire to also benefit from the perceived "spoils" of the fishery. Disputes often occur between the fishers and the LRFF trade operators, usually centered on use rights to fish areas and the prices being paid to the fishers. Virtually everywhere the LRFF trade has operated, there have been disputes, many of which continue well after the LRFF operators depart.

[109] Johannes and Riepen 1995.

One direct result of the LRFF trade and the way it has developed and affected coastal societies is the pervasive increase in the extent of corruption at most levels of the trade.[110]

While incapacitation and loss of men in fishing communities due to diving accidents has been recognized as a major social impact of this trade, a less acknowledged effect is the disruption to community life as a result of men neglecting their community and social obligations. The remoteness of many fishing grounds, coupled with the intensive "pulse" fishing that generally occurs, means that fishers are away for extended periods.

Socioeconomic Concerns in LRFF Fisheries

A major issue for many fishing communities is the waste of resources associated with the trade. The high proportion of bycatch and high mortality rates of fish transported by sea are characteristic of the trade. In many areas, it is not possible for all the bycatch to be used for other purposes and so is wasted. Similarly, concerns have been expressed over the use of valuable food fish to feed the caged live fish, especially in villages where poverty is severe or protein resources are scarce.

In most areas where the LRFF trade has operated and moved on, legacies remain. The first of these is the introduction of destructive fishing methods, for example the use of cyanide in fishing (dispensed from squirt bottles and through the use of cyanide-laced baits for trap and hook-and-line fisheries) and use of chunks of live coral to weigh down or camouflage traps.

In many areas, LRFF operators have encouraged the targeting of reef fish spawning aggregation sites. While many of the sites may already have been known to local fishers, they may not have been targeted as intensively, or communities were in part already reliant on these aggregations for subsistence. Where the spawning aggregations were not known, the LRFF operators have deliberately searched for and targeted new sites. From experiences in many parts of the Indo-Pacific, once these aggregations are fished out they may not return, resulting in a direct loss to communities that used them for subsistence, and also an indirect opportunity cost.

[110] Johannes 1997; Erdmann 2001, 2002; Lowe 2002.

Another legacy is the loss of fish and reef resources and opportunities as a result of overfishing the target fish and using destructive fishing methods. On less productive reefs, there is more incentive to use other destructive methods such as blast fishing, and to continue using cyanide.

Continued poverty and indebtedness are also a recurrent consequence of the LRFF trade. Any short-term gain from the trade is usually followed by a long-term loss. For example, the degradation or elimination of spawning aggregations may not only affect subsistence fishing potential (resulting in a possible need for food substitution), but also eliminate an opportunity for alternative activities, such as scuba diving on aggregations or other ecotourism-related activities. Nevertheless, some communities have benefited from the trade through "fish-for-mosque or church" deals with fish traders; although the long-term costs of such arrangements may still be significant.[111]

Socioeconomic Concerns in Aquaculture Operations

A major issue in regard to socioeconomic benefits from aquaculture is the ability of the poor to access and benefit from this technology.[112] Hatcheries, in particular, require substantial capital investment and training, and may be less accessible to poor people because of the limited availability and high repayments costs of capital.[113] In Bali, it is the larger hatcheries (often supported by Javanese or Chinese investment) that have the greatest capacity to culture live reef fish, because of their ability to diversify their operations and absorb the higher risk that is inherent in culturing these species. The smaller hatcheries tend to concentrate on milkfish culture which, although less profitable, is also less risky.[114]

However, the widespread practice of grow-out of small LRFF taken from the wild entails severe ecological and environmental problems (discussed in Chapters 3 and 6, respectively) that can affect not only the sustainability of the culture operations but also of other subsistence or commercial fisheries for these species.

[111] Thorburn 2001, 2003.
[112] Haylor et al. 2003.
[113] Haylor et al. 2003.
[114] Siar et al. 2002.

5 MANAGEMENT OF THE TRADE

The major issues concerning the LRFF trade, as noted in Chapter 1, are overfishing including fishing on spawning aggregations,[115] destructive fishing,[116] wastage of both target and nontarget fish, capture of threatened species, and various social issues. Development of a sustainable LRFF fishery requires management measures to be targeted at the fishers, traders, and/or consumers. Correspondingly, there are three approaches to regulating the trade:

- fisheries management per se, i.e., managing fisheries by limiting their size (quantities of fish taken) and scope (areal and/or seasonal fishing closures);
- demand-side and trade controls using national, regional, and international mechanisms; and
- influencing consumer behavior, through codes of practice, industry standards, and consumer outreach programs.

The role that aquaculture of LRFF plays in the trade is discussed in Chapter 6. This subsector requires careful management 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 organizations in broader aspects of managing the trade. These are discussed in Chapter 7. Finally, social issues, which have an impact on the success of managing the LRFF fisheries, are described in Chapter 4.

[115] Sadovy and Vincent 2002.
[116] Johannes and Riepen 1995; Barber and Pratt 1997; Pet-Soede and Erdmann 1998.

FISHERIES MANAGEMENT: METHODS AND IMPLEMENTATION

In most countries where LRFF fisheries have become established, they coexist alongside or in close proximity to traditional subsistence fisheries. This overlap implies that the impact of fishing activity for LRFF trade cannot be viewed in isolation.Managing the LRFF fishery and any coexistent non-live fisheries that target the same populations will require monitoring the activities of all resource users including fishers, buyers and/or brokers, wholesalers and retailers, government agencies, and trade associations.

Tropical reef fish fisheries tend to target many diverse species, use multiple fishing methods, involve many fishers, and be spatially dispersed, with many landing points. This complexity and a general absence of biological data make the assessment and determination of sustainable levels of harvest for all fishery sectors especially difficult, as described in Chapter 3. A characteristic feature of tropical small-scale fisheries, such as those where the LRFF trade occurs, is their "physical" (geographic, socioeconomic, and political) remoteness from decision makers.[117] This remoteness makes the effective implementation of management tools to control the degree of exploitation of target and nontarget species extremely difficult.

In fact, most LRFF-producing countries do not have a management strategy specifically for these fisheries[118] and few countries have specific legislation to preclude LRFF fisheries commencing or to close a LRFF fishery down once established. In many countries where the trade in LRFF is well established, the fishery is managed on an ad hoc basis or there may be no management of reef resources at all.

There is a range of conventional management options available for managing LRFF fisheries as well as regulatory tools that may be unique to LRFF fisheries. Basically, they can be grouped into controls over inputs and controls over outputs. This section examines some of the relevant management options. The advantages and limitations of the various tools in the context of the

[117] Pauly 1998.
[118] Exceptions are PNG and the Solomon Islands, which are in the process of finalizing management plans explicitly for their LRFF fisheries.

LRFF trade are described in Appendix 1 and a summary of the current situation is given in Appendix 2.

Input Controls

Licensing

Licensing of fishers and/or foreign operators is one of the strongest mechanisms available to manage LRFF fisheries, in that it can recognize traditional reef ownership, create resource rents, and limit entry so as to control the intensity and location of LRFF fishing activities. The effectiveness of licensing programs however, is hindered by a lack of cohesion between and enforcement capacity of various tiers of authority. The requirement to negotiate access agreements with traditional owners, in conjunction with provincial or national government approval, while complex, can safeguard the resource and serve as a means for communities to extract payments from industry in exchange for access to the resources.[119] In reality, the high value of the resource, along with weak enforcement capacity and official corruption, has tended to erode the effectiveness of customary marine tenure in controlling LRFF trade activities. Disputes, whereby some traditional owners have welcomed the trade and others have not, have seen communities and governments close down LRFF fisheries.

The prospect of issuing licenses and maintaining a license program for many hundreds or thousands of subsistence fishers is limited. In many countries, licensing will likely be more effective when targeted at buyers or exporters. In Indonesia, for example, foreign companies that hold a license to export LRFF are permitted to fish only outside the 12-nautical-mile zone and license fees are based on the ships' fish holding capacity. Unfortunately such companies do not need a license to collect and export fish caught by local fishers, although such a requirement would allow better monitoring of export volumes.[120] In the Philippines, the export and transport of fish and fisheries products require permits from the Bureau of Fisheries and Aquatic Resources. License conditions require that the exporters maintain and submit records on the

[119] In general, fishing licenses granted by national or provincial governments will be contingent on access agreements negotiated at a local level.
[120] Bentley 1999.

number and species of fish exported.[121] The fishery on the Great Barrier Reef, Australia, is a limited-license regime, requiring operators to be endorsed to catch and market coral reef finfish in either frozen or live form. Fishing effort is regulated via a cap on the total number of commercial licenses. Recently, a total allowable catch was allocated amongst license holders based on catch history. Licenses are fully transferable and can be freely bought or sold.[122]

A high degree of caution in some producer countries that have recently entered the trade is reflected in their use of "trial fishing" periods. Trial fishing allows limited fishing under strict and closely monitored conditions,[123] and can be used to collate data for further assessment.[124] Trial fishing represents a special form of licensing, used to grant permission to foreign vessels to fish commercially or to export fish for the specified trial period. The success or otherwise of this approach will hinge on a country's ability to implement and enforce a licensing program. PNG, Fiji Islands, Marshall Islands, Seychelles, and Vanuatu[125] have all previously established trial fisheries.

Moratoriums

The use of destructive fishing practices (e.g., cyanide), disputes over payments to fishers, concerns over impact of fishing on fish populations, and conflict between fishing communities over access to fishing grounds have all led to decisions to impose moratoriums on LRFF fisheries.[126] Access disputes tend to predominate in Pacific Island countries where coastal communities hold customary tenure rights over marine resources,[127] and are the result of increases in value of nearshore

[121] A. Alverez, personal communication.
[122] G. Muldoon 2003 (unpublished report).
[123] Management measures include, total allowable catch limits, use of hand-lines 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.
[124] Gisawa and Lokani 2001.
[125] For the Seychelles, see Bentley and Aumeeruddy 1999; the Marshall Islands, Smith 1997; the Fiji Islands, Yeeting 1999b; Vanuatu, Naviti and Hickey 2001.
[126] Johannes and Lam 1999; Donnelly et al. 2000; Padilla et al. 2003.
[127] See Hviding (1996) for a more detailed description of customary marine tenure practices in Melanesia.

resources. There has been a history of ad hoc moratoriums in response to biological, economic, or social concerns, but governments have also used moratoriums in a planned way to limit access to resources by foreign operators.

PNG, Marshall Islands, Solomon Islands, Seychelles, and Vanuatu[128] have all imposed moratoriums on fishing following trial fishing activities, although PNG still has an ongoing trial operation. In the northern Calamianes Islands of the Philippines, a moratorium on the export of LRFF was put in place during 1993–1998 in response to biological concerns. The reinstatement of this moratorium has continued to be promoted by some community members.[129] Similar biological concerns resulted in moratoriums in several parts of PNG since the trade began there in 1991[130] and in parts of the Fiji Islands.[131] In some countries, moratoriums have since lapsed (e.g., the Marshall Islands and Fiji Islands) and LRFF fishing activities have recommenced despite ongoing sustainability concerns. The moratorium in the Solomon Islands was lifted in December 2000, and the fishery is considered "open," but no LRFF fishing activity has since commenced.

Gear Restrictions

Fishing practices can be regulated through gear restrictions that permit specific fishing techniques, such as handlining, and prohibit others, such as dynamite and cyanide fishing. In a few countries, such as Australia, the Maldives, and PNG, handlines are the only prescribed means by which fish can be captured, although in most Pacific countries cyanide is not an issue. In all countries engaged in the trade, hook-and-line techniques are widely practiced, but usually, alongside destructive fishing techniques, predominantly traps weighted using pieces of live coral (some in which cyanide-fed bait fish are used to anesthetize the target species) and hand nets. The use of compressor diving should be discouraged, given its association with cyanide, overfishing, and diving injuries and deaths.

[128] For PNG see Gisawa and Lokani 2001; Marshall Islands, Smith 1997; Solomon Islands, Donnelly et al. 2000; the Seychelles, Bentley and Aumeeruddy 1999; and Vanuatu, Naviti and Hickey 2001.
[129] N. Brucal, personal communication.
[130] Richards 1993; Johannes and Riepen 1995.
[131] I. Tuwai, personal communication.

The focus in many countries where a LRFF fishery is well established has been on curbing destructive fishing practices by prohibiting the use of poisons, such as cyanide. Indonesia, Malaysia, and Philippines have such regulations at the national and provincial levels.[132] In the Philippines, a network of cyanide detection laboratories was established in 1994 by IMA, with the assistance of the Philippine Bureau of Fisheries and Aquatic Resources, to facilitate enforcement.

Outreach and training efforts have been made in many areas to induce fishers to switch from destructive to nondestructive gear.[133] There has been little follow-up work, however, to gauge the long-term success or sustainability of these initiatives.

Zoning

Zoning can control the distribution of fishing effort. Areas can be closed seasonally (e.g., to protect spawning aggregations) or permanently as protected areas to act as harvest refugia that provide havens for a portion of the fish populations. Zoning can also be used to address potential user conflicts so as to separate or protect user groups (e.g., subsistence fishery or ecotourism).

The vulnerability of groupers and humphead wrasse while aggregating to spawn has been widely recognized.[134] Some countries—Palau, Pohnpei, PNG, and in Indonesia (Komodo National Park)—have sought to protect aggregation sites from overfishing through seasonal and spatial closures. On the Great Barrier Reef in Australia, seasonal closures have recently been included as part of a new management plan, while legislation to protect known aggregation sites is also being considered. Elsewhere, such as in the Komodo National Park, the Great Barrier Reef, Ha Long in northern Viet Nam, Coron in the Philippines, and parts of the Pacific, marine protected areas have been established, the extent of which varies widely.[135] Such closures are not necessarily in direct response to LRFF fisheries, but as a means of

[132] Bentley 1998.
[133] Barber and Pratt 1997; Barber and Cruz 1998; Erdmann and Pet-Soede 1998; Pet and Djohani 1998; Barber 1999.
[134] Sadovy et al. 1994; Domeier and Colin 1997; Johannes et al. 1999.
[135] On the Great Barrier Reef, it is estimated that approximately 30% of all reefal areas will be permanently closed to fishing for reef fish under new conservation management measures, but the proportion, if any, is much less in other countries.

conserving coral reef ecosystems and enhancing fishery catches through spillover effects.[136]

Output Controls

Catch Quotas

Catch quotas can help to maintain catches within sustainable limits. However, they have limited application in tropical, inshore multispecies fisheries that support LRFF fisheries because of the limited biological and ecological knowledge of the target fish. Catch quotas are not enforced in any of the countries currently engaged in the LRFF trade, except Australia, under proposed new management measures; the Seychelles when the fishery was active there; and PNG.

Export Control

Some countries have sought to protect the more vulnerable LRFF target species by prohibiting their export for the trade, although the effectiveness of such measures varies, usually according to enforcement capacity. In Indonesia, commercial export of certain sizes of humphead wrasse is nominally prohibited. However, under specific conditions, local fishers are able to sell these wrasse to collecting companies that have obtained a business permit. Catch and export of humphead wrasse is also banned in northern Palawan, Philippines, while a memorandum of understanding between fishers and dealers in Australia has reduced "live only" exports of humphead wrasse to zero,[137] while the prohibited export of humphead wrasse from Palau is well enforced.[138]

Fish Size Limits

Limits on the size of fish that can be caught help to ensure adequate spawning population. Presently, minimum and/or

[136] Russ and Alcala 1996; McClanahan and Mangi 2001.
[137] Under new fisheries legislation, the capture of humphead wrasse and humpback grouper for both live and frozen markets will be prohibited.
[138] Author's (TG) observation.

maximum size limits across a wide range of species apply only in Australia and PNG, while Palau has a minimum size limit on one species, the humphead wrasse. In Indonesia, size limits have been decreed on humphead wrasse for export but these limits (above 1 kg and below 3 kg) are market, not biologically, based and not enforceable. Application of size limits on grouper species has been recommended in other exporting countries including the Maldives, Philippines, and the Pacific.[139] With the exception of the Philippines, an absence of biological data has meant size limit recommendations are based on combination of known biology of specific species and market requirements. In Indonesia and in the province of Palawan, Philippines, there is an exemption to the minimum size if the undersize wrasses are used for aquaculture. In effect, this offers no protection to the fish because they are exported when they reach market size. They certainly have not had the opportunity to reproduce, which is the biological reason for the minimum size limit.

Mode of Transport

A number of countries engaged in the LRFF trade regulate the conditions under which the fish are transshipped, requiring loading of catches to take place from designated ports, thereby strengthening the ability to monitor exports. In Australia and parts of Palawan, the use of live-fish transport vessels is banned, although the restrictions are circumvented in Palawan by transferring fish to other parts of the province.[140] In both Indonesia and the Philippines, permits are notionally required to transport or export LRFF, while fishing by live-fish transport vessels inside local or national waters is prohibited. In both countries, these regulations have proven ineffective.[141]

Generally, the mode of transport employed depends on distance to markets in Hong Kong, China and mainland PRC and the viability of shipping LRFF by air. In some of the main exporting countries—Indonesia, the Philippines, and Australia—shipments

[139] Shakeel and Ahmed 1997; Smith 1997; Yeeting et al. 2001; Padilla et al. 2003.
[140] N. Brucal, personal communication
[141] For example, in the Philippines, a ban on foreign-owned live-fish transport vessels in southern Palawan is circumvented by transhipping LRFF to northern Palawan via locally-owned vessels and loading them onto foreign transport boats for export. Author's (YS) observation.

by air are approximately 50%, 90%, and 100%, respectively of total exports. Limited infrastructure in many countries precludes shipping of fish by air. In the Indian Ocean— the Seychelles and Maldives—and parts of the western Pacific, all transshipments are, or were, by sea. In these regions, a combination of distance to market, historically lower prices since 1999 (see Chapter 2) and the absence of air transport options may have contributed to the infrequent and irregular exports of LRFF on financial grounds—effectively a proxy output control.

Traditional Controls

In the absence of management capacity, traditional ownership may be a way to control fishing activity, for example by licensing or area closures and local surveillance or enforcement. Customary marine tenure prevails throughout many Pacific countries of the region, such as the Fiji Islands, Kiribati, Palau, PNG, Solomon Islands, Tonga, Vanuatu, and Marshall Islands, and is recognized by provincial and national governments. It grants communities and clans ownership of their nearshore fishing grounds and the right to decide who can access these resources.[142] Similar customary laws, *Sasi*, prohibiting outsiders from fishing commercially in village fishing grounds, also exist in Indonesia,[143] although these traditional laws are not acknowledged by the State.[144]

In the Philippines, the province of Palawan has been granted control over managing its LRFF fishery resources; through the Palawan Council of Sustainable Development, and the provincial laws have sovereignty over national laws.[145] The decentralization of marine resource management in Indonesia has resulted in local and provincial control over LRFF fisheries. However, the lack of coordination between various levels of government effectively cripples any effort to control the trade.[146] In parts of the Pacific—Solomon Islands and PNG—customary marine tenure has been used to establish no-take zones.[147]

[142] Hviding 1996.
[143] Adhuri 1998.
[144] Ministry of Marine Affairs and Fisheries 2002.
[145] Padilla et al. 2003.
[146] Ministry of Marine Affairs and Fisheries 2002.
[147] Donnelly et al. 2000; NFA 2002.

Monitoring

Effective management requires active fisheries to be carefully monitored in terms of the resource and fishing effort and fish mortality. There are two general types of data that may be collected: fishery-independent data, which assess the resource independently from the commercial fishery (for example by underwater visual census or experimental fishing[148]); and fishery-dependent data that evaluate the resource taken by the fishery itself (for example catch per unit effort and biological data on size, age, and sex). Data should be collected at regular intervals over the long term and according to established protocols specified for each fishery. Sustained monitoring of target species and by-catch allows for effective regulation of resources, adaptive management, and the prevention of overfishing and depletion. To be meaningful, data must be species-specific and not aggregated by group (i.e., a single data set for each species of grouper versus lumping all species under the term "groupers").

Monitoring and reporting of export volumes are undertaken in most countries engaged in the trade, although the reliability of these records is generally questionable and trade volume is almost certainly underestimated. With the exception of Australia and PNG, LRFF exports are not disaggregated to a species level. Moreover, misreporting of species and inclusion of non-live reef fish in export data is commonplace. At an aggregate level, "official" data tend to underreport exports because of the physical remoteness of fishing areas and the use of live-fish transport vessels, which results in fish movements being unrecorded both leaving the source country and upon arrival in Hong Kong, China (see Chapter 2).

PRIORITIES FOR MANAGEMENT

An outstanding question with regard to managing LRFF fisheries is whether it is even possible to prosecute a sustained, beneficial fishery. At issue is both whether the enterprise of LRFF

[148] Samoilys 1997; Connell et al. 1998.

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. The main problem plaguing LRFF fisheries in many areas is overfishing, whether associated with destructive fishing or not. Overfishing is particularly difficult to address in reef fish fisheries and successful management of LRFF fisheries can only occur where there is strong and resolute enforcement.

The industry's frequent pattern of developing boom-and-bust fisheries, progressively farther from the market; its apparent reliance on destructive fishing methods; and the regular use of sea transport to collect fish from remote landing sites are all poor indicators of economic and biological viability. Even in countries whose experiences with the LRFF trade have not resulted in serious environmental impact, LRFF operations have generally been short-lived, often lasting no more than two or three years. Reasons include declines in catch rates, local concerns about competition with other uses of the resource, and local participants being dissatisfied with their returns.

Even the LRFF fishery on the Great Barrier Reef (GBR) with its extensive fishing grounds, supported by strong management capacity and good understanding of biological resources, is considered to be threatened from overfishing. Although a limited-license fishery, the GBR fishery was characterized by a large amount of unused capacity or *latent effort*.[149] Value adding of the main target species in this fishery (see Chapter 2) has provided an economic incentive for mobilization of this latent effort and led to concerns that levels of fishing effort are becoming unsustainable.[150]

Enforcement

Whether the aim is to develop a sustained, beneficial LRFF fishery, keep the fishery closed, or merely mitigate its adverse effects, the management response will be costly, requiring administration, enforcement, outreach and training, and

[149] Latent effort is the difference between actual fishing effort applied and the potential effort, if all license holders were to fish to their capacity.
[150] Mapstone et al. 2001.

monitoring, along with building capacity. Without the political will to establish and enforce policies for a LRFF fishery, investment in capacity enhancement will not pay off. Conflicts of interest and corruption from both community authorities and all levels of government are common across countries engaged in the trade.[151] Overcoming these weaknesses, or working around them, is often the single most important management challenge. In order to compensate the public and help rationalize the behavior of the industry, it is generally good practice to try to recover these costs from the industry, such as through license fees.

Tropical reef fish fisheries usually comprise many types of fish and fishing methods, are spatially dispersed, and have many landing points. For these reasons, effective management should not be dependent on detailed data and analysis nor intensive surveillance.[152] But characteristics of LRFF fisheries are quite different than the broader reef fish fisheries of which they are a part, which can both assist and hinder their regulation.

On the one hand, enforcement of management regulations and monitoring of catch and effort should be relatively easy because the fisheries target few species, fishing activity is often spatially concentrated, and exports from some countries are funneled through few points. Bottlenecks on the demand side suggest that enforcement on such issues as listed species could be exercised at major import markets. On the other hand, the remoteness of many fisheries, their long distance from centers of power, and the large number of subsistence-level participants are difficult obstacles to overcome. Lack of institutional and enforcement capacity and a limited willingness on behalf of responsible authorities to impose management restrictions remain a key impediment to successfully managing LRFF fisheries. The prospect of bilateral agreements between export and import countries appears remote given the central role played by Hong Kong, China buyers in source countries and the reluctance of these buyers to reject undersize or cyanide-caught fish upon arrival. Efforts to strengthen enforcement in source countries through using local onboard observers on foreign fishing vessels have been mostly unsuccessful, again as a result of corruption.

[151] Adhuri 1998; Lowe 2002.
[152] e.g., Johannes 1998.

Curbing the destructive effects of the trade, both in established and developing LRFF fisheries including practices such as cyanide fishing, is often prevented by governments complicit in the trade, usually upon the receipt of small royalties that highly undervalue the resource final value.[153] Moreover, 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 management reliant on that data.

Clearly, high priority should be put on curbing the use of destructive fishing methods. In encouraging the use of handline technology, the main obstacle is that most parts of the region are already overfished as evidenced by declining catch rates in the Philippines[154] and Australia.[155] Moreover, cyanide has been shown to be a more efficient capture technique purely in terms of numbers of fish caught and also average size of fish.[156] Ironically, the use of cyanide tends to exacerbate levels of mortality before the catch reaches the consumer, although traders have already factored in the costs of this and other types of mortality to their costs. Poor handling husbandry, holding, and transportation practices will exacerbate this mortality, which ranges up to 80%.[157]

One important strategy for preventing fish population depletion is keeping especially vulnerable species and large portions of the reef off-limits to the LRFF fishery. The permanent closure of particular areas, in this case obviously including those where spawning takes place, is increasingly being held by scientists as an important way to avoid depletion of fisheries resources worldwide. To be effective, these closed areas have to be big—at least 20% of the total area of an ecosystem is the consensus at present.[158]

Wild harvest of juveniles and fingerlings for grow-out has also been identified as posing a significant biological threat (Chapter 3).[159] Given capacity limitations in many source countries, the use of closed areas to protect these juvenile and immature fish may be easier to enforce than size limits or gear restrictions.

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[153] Pet and Pet-Soede 1999.
[154] Padilla et al. 2003.
[155] Queensland Fisheries Service, unpublished data.
[156] Bentley 1999.
[157] Sadovy 2002.
[158] Pauly and Maclean 2003.
[159] Sadovy 2000; Sadovy and Vincent 2002.

Certain characteristics of the LRFF fisheries identified earlier in this section suggest that enforcement and monitoring efforts will be more effective if targeted further along the market chain (i.e., relatively fewer participants and holding facilities). Moreover, increased use of air transport from source countries in Southeast Asia (Chapter 2) has meant controls requiring high-coverage surveillance or regular quantitative monitoring, such as fish size restrictions or limits on amounts of fish caught or exported, have become more cost effective.

While most attention focuses on destructive fishing practices, the widespread use of specialized live-fish carrier vessels in areas where shipping fish by air remains unfeasible is also a primary cause for concern. Their requirement for a minimum profitable payload of 10–15 t of fish[160] poses a danger to the sustainable exploitation of fish populations, because it sometimes encourages the targeting of spawning aggregations to maximize catches over short periods (Chapter 3 addresses this issue).

Improving Fish Survival

Keeping the catch alive and healthy is obviously an important objective in a live-product fishery. Fish handling techniques can be improved through outreach to fishers[161] and in many cases there is room for improvement in holding and transport technology. Progress in the former has been made in several countries, leading to improved survival, although the long-term success of such initiatives will depend upon the capacity and willingness of countries to support the programs in the absence of external assistance. Poor holding and husbandry practices, which persist in many source countries using cage facilities, is an aspect of the trade requiring concerted attention. Air transport can, when done properly, reduce mortality of the fish, but is often cost prohibitive and unavailable in many areas.

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. An important constraint for operations that ship by sea is that large amounts of fish (10 t or more, depending on the distance[162]) must be shipped

[160] P.Chan, personal communication
[161] Pratt 1998; Johannes et al. 1999; Anderson et al. 2003.

in order to make the trip cost effective. Evidence suggests that the long collection times required to catch the minimum carrier-vessel shipment size can result in high losses of fish in holding pens.[163] The economic and biological costs of holding the catch for long periods— feeding costs, the volume of feed fish needed, and mortality—are much higher where sea transport is used (see Chapter 2).

If there is ample frequency of flights, satisfactorily brief routes, and reasonable shipping rates, small shipments can be made by air, in which case the costs of holding the fish are less important and harvest rates can better "afford" to be trimmed to within the limits of the resource. Governments can require live fish to be shipped by air—Australia does just that—but their ability to create a transportation system that would make by-air transport economically feasible is, of course, limited.

If air transport is not feasible and if the overall harvest rate is to stay within the limits of the population, two strategies used to minimize holding costs could be:

- coordinating transport operations across multiple fishing areas to spread effort and catch for a given shipment across a broader area; or
- fishing a given area in brief but intensive pulses, producing, for example, the entire year's harvest and an entire vessel shipment in just a few weeks.

Either of these alternatives could be achieved through seasonal closures/openings to make sure spawning aggregations are untouched. They should take into account seasonal variations in price and the cultural or economic patterns of fishing communities. Pulse fishing may have the advantage of reducing enforcement and management costs because of the concentration of effort over a specified time.[164]

[162] Note that shipments from Indonesia and the Philippines can be as low as 3–5 t.
[163] Johannes and Lam 1999.
[164] Graham 2001a.

National Coordination and Regional Cooperation

Export fisheries call for strong national-level control, but with the exception of Australia, national policy and control over LRFF fisheries have largely proven ineffective. Likewise, as shown earlier, coordination between national, provincial, and local government in most countries involved in the LRFF trade has been limited to date.[165] Where customary marine tenure over nearshore resources is strong, effective national–provincial–local cooperation is essential. National-level controls should require that permission to access LRFF be obtained from customary reef owners and the relevant provincial government(s), so as to prevent localized depletion, protect spawning grounds and threatened species, and minimize conflict and competition between resource users.

There has been little formal cooperation among producer countries in dealing with the LRFF trade. One regional approach that has been considered is maintaining a registry of companies and vessels involved in the trade, for the purpose of sharing information about "good" and "bad" players and possibly for blacklisting bad players. A more costly option would be to develop a centralized vessel monitoring system, in which transport and supply boats are required to carry and continually operate position transmitters.[166] In order to cope with the possibility of poaching in remote areas, the cooperative agreement underpinning the system would have to include key parties on the market side, namely the foreign companies that partner domestic operations in source countries. Only then would there be the possibility of ensuring that all vessels involved in the industry are subject to the monitoring requirements.

DEMAND-SIDE AND TRADE CONTROLS

While the focus so far has been on supply side management to improve fishery practices and mitigate negative impacts of the LRFF trade, demand countries, most notably Hong Kong, China and

[165] See also Ministry of Marine Affairs and Fisheries 2002, p.30–34.
[166] Richards 1999

mainland PRC—the largest consumers of live reef fish—need to take more responsibility for the biological and socioeconomic consequences of the LRFF trade on supply countries.

Low prices paid by consumers since 1999 have highlighted the important role of consumers of LRFF in dictating the extent of the trade's influence. Lower prices have meant the viability of transporting fish across large distance to consumer markets from countries, where transport by sea remains the only option, are no longer as attractive to traders (e.g., South Pacific).

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.[167]

National, Regional, and International Mechanisms

The Hong Kong, China Government has taken a positive step in regulating the trade by revision of the harmonized code to facilitate monitoring of imports (see Chapter 2).[168] The AFCD has begun to address destructive fishing practices in Hong Kong, China via a program of education, monitoring, and enforcement,[169] but the success of this program appears limited. Development of a regional LRFF trade agreement through Asia-Pacific Economic Cooperation (APEC) would likely be of limited success because APEC is not a negotiating body and although a regional agreement may be of value, bilateral agreements between APEC economies are more appropriate for addressing issues of mutual concern. A multilateral approach by affected APEC supply economies, however, could encourage the Hong Kong, China Government to strengthen its enforcement activities against perpetrators of illegal and/or irresponsible fishing practices there, when such activities are bought to their notice by affected source countries.

[167] Cesar et al. 2000:150–153
[168] McGilvray and Chan 2001.
[169] Sham 1997.

Several different models have been proposed for achieving collaborative resource management including certification and eco-labeling, voluntary codes of conduct, and industry standards. Of these models, certification and eco-labeling are considered less appropriate because of the large volumes and number of species traded, the diffuse nature of the industry and the uniquely "live" aspect of the product. Industry standards, while difficult to institute for the same reasons, may, when promoted as a voluntary code, be a more suitable model for the LRFF trade.

Codes of Practice and Industry Standards

The need for a voluntary code of practice for the LRFF trade has been recognized at the highest levels.[170] Effective standardization[171] can help international trade by removing differences or practices that constitute barriers, ensure a consistent quality of product, improve the health and safety of industry participants, and protect the environment. Standardization results from consensus agreements reached between all economic players in an industrial sector—suppliers, users, and often governments.

Currently a standardization project is underway, led by The Nature Conservancy and the Marine Aquarium Council, to develop industry standards for the LRFF trade. The goal of the project is to bring together stakeholders and build a consensus on what "best practices" are needed to improve the conduct of the industry and move toward industry sustainability, encompassing reefs, fish populations, and fishing communities. The project focuses on both wild-caught and cultured fish and covers standards and practices relating to assessment of fish populations, capture and culture methods, holding, transportation, and human health and safety concerns.

[170] The development of standards and protocols under a code of practice was a key recommendation of the APEC Workshop on Destructive Fishing Practices on the Marine Environment, held in Hong Kong, China in 1997.

[171] Standards in this sense are documented agreements containing technical specifications or other precise criteria to be used consistently as rules, guidelines, or definitions of characteristics, to ensure that products, processes are fit for their purpose.

INFLUENCING CONSUMER BEHAVIOR

In many countries, consumer environmental awareness 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, China and mainland PRC where environmental awareness is as yet underdeveloped. Three research projects have been carried out in recent years on consumer attitudes and preferences in relation to LRFF. The major findings from these studies are:

- Taste, texture, and freshness of the fish are the key factors for choosing to eat LRFF. More people prefer wild-caught fish than cultured fish. In one study, more than a quarter of consumers stated that they would not find cultured fish an acceptable alternative due to the perceived inferior taste.[172] In contrast, a "blind" taste-test study found that consumers of a particular low-value grouper species favored cage-reared over wild-caught fish, but for a high-value grouper favored wild-caught fish.[173] Lastly, most consumers saw the reduced risk of ciguatera poisoning as the main reason for switching to cultured species.[174]
- Awareness of environmental and conservation concerns relating to the LRFF trade was found to be very low; almost half of the interviewees had never heard of fishing using sodium cyanide, and over 80% knew nothing of its destructive effects on coral reefs. Awareness of the vulnerability of key species of the trade was likewise low.
- At least one LRFF currently found on the market, the orange-spotted grouper, is now rarely sourced from the wild as adult individuals. Large numbers of orange-spotted grouper are available from aquaculture operations and the market will not meet the prices demanded for this fish from the wild. Restaurateurs and importers can influence consumers' preference without the consumers being aware of it.

[172] Omnitrak 1997. Note that it is not known whether the cultured fish were wild-caught and grown-out or from full-cycle aquaculture.
[173] Chan 2000.
[174] Chau 2001.

As environmental awareness increases in Hong Kong, China and mainland PRC, and indeed throughout the region, consumer choice will become more common, making early consumer awareness programs and campaigns important, particularly among the young, who will be the consumers of tomorrow.

Such programs could also include a form of eco-labeling, labeling products that conform to certain environmental standards. In the case of fisheries, the Marine Stewardship Council certifies fisheries as well-managed and sustainable according to a set of principles.[175] The Audubon Society and the Monterey Aquarium provide listings of common seafoods in the United States for consumers using a simple color code, from green (plentiful) to red (overfished). Labeling of LRFF could be done on menus or display tanks, but would require much more knowledge about the individual species than is currently available, and agreement on standards by respected international bodies.

[175] The Marine Stewardship Council is an independent NGO representing a partnership between the World Wide Fund for Nature and Unilever. The objective is to provide a system of certification of seafoods based on a broad set of standards for sustainable fishing. See www.msc.org

6 AQUACULTURE

SCOPE AND PRODUCTION

Aquaculture, aquatic farming, can be defined broadly as an intervention in the rearing process that enhances production, such as feeding and protection from predators. With regard to the LRFF trade, this definition covers a range of activities from full-cycle aquaculture to short-term holding and feeding of wild-caught fish to "fatten" them or to take advantage of market price fluctuations. Although there is a range of species supplied to the trade,[176] this chapter focuses on groupers, because groupers are among the highest-value fish in the trade and consequently are the fish favored by farmers. Snappers are also in demand in live fish markets, but because they generally bring lower prices than groupers, there has been less emphasis on snappers. Many snappers are produced for local markets, rather than the "high-end" export markets in Hong Kong, China and southern mainland PRC.

Most aquaculture production of groupers in the Indo-Pacific, as reported to FAO, is from Taipei,China and Indonesia (Table 6.1). However, mainland PRC produced an estimated 8,256 t of groupers in 1997 according to unofficial reports[177] and production there is likely to have increased substantially since then. Viet Nam produced an estimated 2,600 t of marine fish in 2001, of which a high proportion was cultured groupers.[178] Thus, the regional total production of groupers through aquaculture in 2001 may have been around 25,000 t.[179] The value of production of the fish reported to FAO in 2001 was $89 million. On this basis, the total value of grouper aquaculture production in the region in 2001, including mainland PRC and Viet Nam, was about $173 million.

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[176] Lau and Li 2000.
[177] NACA/TNC 1998.
[178] Le 2002.
[179] Based on a conservative 10,000 t for PRC, and 2,000 t for Viet Nam.

Table 6.1: Indo-Pacific Aquaculture Production (t) of Groupers Reported to FAO by Country, 1992–2001

Country	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Hong Kong, China	55	632	627	620	1,110	1,036	312	280	523	910
Indonesia[a]	–	–	–	–	–	–	–	1,759	1,159	3,818
Korea, Republic of	–	–	–	–	9	–	–	–	–	–
Kuwait	–	–	–	–	–	–	–	5	6	20
Malaysia	288	1,006	931	834	857	799	465	948	1,217	1,101
Philippines[b]	<0.5	63	18	10	36	158	115	145	151	97
Singapore	233	147	133	101	93	82	97	94	111	185
Taipei,China	1,125	3,845	1,749	1,899	1,789	2,525	3,471	4,112	4,992	5,285
Thailand	965	755	1,078	674	774	795	1,390	1,143	1,332	1,442
Total Volume (t)	2,666	6,454	4,536	4,138	4,668	5,395	5,850	8,486	9,491	12,858

[a] A recent estimate of grouper production in Indonesia for 2001 was 7,670 t (Asian Aquaculture magazine, September – October 2003 issue).
[b] The FAO data for the Philippines previously showed significantly higher production up to 2000, most of which was from brackishwater grouper culture. However in 2001, the year discussed in this text, the additional amount from brackishwater was only 39 t (making the total 136 t).

Source: FAO Fishery Information Data and Statistics Unit 2003.

Although there is increasing hatchery production of several species, much of the aquaculture production of groupers still comes from fish that are captured from the wild as juveniles and grown out in cages or in ponds in coastal areas.[180] The trade in newly hatched fish (fry) and fingerling-sized fish is complex and widespread in Asia. The annual grouper fry/fingerling catch is estimated to be in the hundreds of millions of fish.[181]

Hatchery Production

The major proportion of hatchery-produced grouper fingerlings originates in Taipei,China. Marine finfish production there is highly specialized into sectors; for example, one farm may produce grouper eggs from captive broodstock, a second rears the eggs, a third rears the juveniles through a nursery phase, and a fourth grows the fish to market size.[182]

The main species cultured in Taipei,China is the orange-spotted grouper. Recently, there has been some production of giant grouper, which is popular among farmers for its hardiness and its rapid growth—it is reported to grow to around 3 kg in its first year. Despite the high level of fingerling production, farms in Taipei,China also rely on wild-caught fry and fingerlings, which are generally imported.[183]

As production technology for groupers and other marine finfish species has improved, there has been increasing development of hatcheries and hatchery production of several species in Southeast Asia. In Indonesia, there is continuing expansion of hatchery production from "backyard" hatcheries. There are an estimated 2,000 units (1 unit = 4 larval rearing tanks) of backyard hatcheries in northern Bali, clustered around the Gondol Research Institute for Mariculture that introduced this technology in the 1990s.[184] The backyard hatcheries are significant sources of employment and economic benefit to the local community.[185] Formerly used mainly for rearing fry of

[180] Johannes and Ogburn 1999; Sadovy 2000; Estudillo and Duray 2003.
[181] Sadovy 2000.
[182] Liao et al. 1994.
[183] Liao et al. 1994; Sadovy 2000.
[184] Siar et al. 2002.
[185] Siar et al. 2002.

milkfish (*Chanos chanos*) for grow-out in other parts of Indonesia and the Philippines for the food and baitfish markets, many of them now also produce grouper fingerlings including humpback grouper and brown-marbled grouper. Larger hatcheries maintain their own broodstock, and sell fertilized eggs to the smaller hatcheries. The hatcheries rear grouper larvae to the juvenile stage, 3–10 cm in length. These are sold to grow-out farms in other parts of Indonesia or overseas.

Indonesian farmers have shown a marked lack of interest in culturing camouflage grouper despite the availability of fingerlings from Balinese hatcheries and the importance of this fish in the Hong Kong, China market.[186] The farmers' main complaint is its slow growth rate in comparison with other groupers, such as the orange-spotted and brown-marbled groupers.[187] Similarly, demand for humpback grouper fingerlings in Indonesia is low because this fish has a reputation for slow growth and susceptibility to disease.[188] Consequently, there is now an oversupply of humpback grouper fingerlings in Indonesia and a large proportion are sold to the aquarium fish market.[189]

There is increasing development of hatcheries in other Southeast Asian countries including PRC, Philippines, Thailand, and Viet Nam. However, grouper culture in these countries (with the possible exception of the PRC) is still largely based on collection of wild-caught fry and fingerlings or importation of fingerlings from Taipei,China.

Production Economics

An economic assessment of the marine finfish hatcheries in Bali, Indonesia, showed that these hatcheries are extremely profitable, with annual returns (profit) of $4,100–65,000; internal rates of return (IRRs) from 12% to 356%; benefit-cost ratios of 1.27:1 to 3.09:1; and capital payback periods for the majority of farms of less than one year.[190]

[186] K. Sugama, personal communication.
[187] James et al. 1998.
[188] K. Sugama, personal communication.
[189] Siar et al. 2002.
[190] Siar et al. 2002.

Evaluations of the profitability of grouper farming in the Philippines by the Aquaculture Department of the Southeast Asian Fisheries Development Center have shown that grouper culture in both ponds and in coastal cages is highly profitable (Table 6.2) with high return on investment and short payback periods.[191]

Table 6.2: Economics of Pond and Cage Grouper Farming in the Philippines

	Ponds (0.9 ha)	Cages (6 x 75 m3)
Annual income[a] ($)	7,920	5,660
Net profit ($)	2,970	2,080
Break-even volume (kg)	–	684
Break-even selling price ($)	–	3.31
Return on investment (%)	82	59
Payback period (year)	1.22	1.68

[a] Exchange rate used was as of June 2003: $1 = P53.45.

Cage aquaculture of high-value species such as groupers is particularly attractive to poor farmers in the Philippines[192]: "This is because grouper can yield a profit margin of as much as $2.50 per kg as against only $0.15 to $0.20 /kg for milkfish. To earn $1,000 one only has to raise 400 kg of grouper as against at least 5,000 kg of milkfish. With an operating capital requirement of $3.00 per kg for grouper and $0.80 for milkfish it would take $1,200 to raise the 400 kg of grouper as against $4,000 for the 5,000 kg of milkfish."[193]

Economic sensitivity analyses have shown how the profitability of grouper grow-out in the Philippines can be increased by improvement in such factors as price of grouper juveniles, feeds, yield, survival and food conversion ratio. In one study, 88–89% of production costs were found to be attributable to fry and feeds.[194]

In Viet Nam, net income from grouper culture ranges from $21 to $89 per month. These incomes range from the lower end of

[191] Baliao et al. 1998; Baliao et al. 2000.
[192] Yap 2002.
[193] Ibid.
[194] Bombeo-Tuburan et al. 2001.

"medium" to the higher end of the "rich" wealth categories in that country.[195]

CONSTRAINTS

The major constraints in the development of sustainable grouper aquaculture are:

- *Availability of fingerlings*. Hatchery production of grouper fingerlings is still well below demand and is constrained by poor and unreliable survival of larvae in hatcheries; few species are available.[196] A regional survey concluded that there were indications that supplies of grouper fry and fingerlings taken from the wild had declined in many areas, and that these declines likely involved overfishing of grouper adults and seed, habitat destruction, destructive fishing practices, pollution, and high export demand.[197] There has also been high mortality of captured fry.[198]

- *Availability of feed supply*. Most marine finfish culture in Southeast Asia relies heavily on the use of small low-value or bycatch fish, commonly termed *trash fish*. The term is inaccurate because these fish would not necessarily otherwise be wasted; alternative uses include reduction to fish sauce for human consumption, protein sources for other agricultural commodities (such as pigs and poultry), and even direct human consumption.[199] The availability of trash fish is often seasonal; for example, fishers may not be able to fish for them during rough weather. The low value of trash fish often means that they are poorly handled, and rancidity and vitamin degradation may lead to nutritional deficiencies in the fish to which they are fed. Feeding losses from trash fish

[195] Haylor et al. 2003.
[196] Rimmer et al. 2000.
[197] Sadovy 2000.
[198] Estudillo and Duray 2003.
[199] New 1996; Tacon and Barg 1998.

are high and increase local pollution in the vicinity of the cages. The use of trash fish may also assist the spread of fish diseases.

- *Use of compounded diets.* There are several constraints to the widespread use of compounded diets for grouper aquaculture. First, farmer acceptance of pellet diets is often low because of the (usually incorrect, as discussed below) perception that these diets are much more expensive than trash fish. Other factors include wastage of pelleted feeds by inexperienced farmers; poor acceptance of pellets by fish fed on trash fish; lack of suitable feed storage facilities in rural areas, which can result in degradation of the pellets, particularly vitamin content, resulting in poor growth and disease in fed fish; and variable product quality, which may also affect farmer acceptance of pellet diets.

- *Health management.* The largely unregulated trade in aquatic organisms for aquaculture in the region is widely recognized as being responsible for the spread of aquatic animal pathogens. Aquaculture of LRFF contributes to this trade through the movement of juvenile fish (both wild-caught and hatchery-reared) throughout the region[200] and, to a lesser extent, the movement of grown-out fish to local or international markets. Of specific concern in relation to groupers are the diseases viral nervous necrosis (VNN – also known as viral encephalopathy and retinopathy, VER) and parasitic blood flukes.[201] Measures are required in order to minimize spread of these and other serious diseases.

- *Environmental impact.* Marine fish culture interacts with the coastal environment in several ways. Environmental changes occurring in some coastal areas caused by non-aquaculture uses have an influence on the success of marine cage culture. The discharge of nutrients in coastal

[200] Bondad-Reantaso et al. 2000.
[201] Bondad-Reantaso et al. 2000.

waters has been blamed for the increased incidence of red tides, which have caused heavy economic losses to fish cage farms in some countries, most recently during 1998 in Hong Kong, China. Environmental impact from culture operations derives mainly from nutrient inputs from uneaten fish feed and fish wastes.[202] These nutrient inputs, although small in comparison with other coastal discharges, may lead to localized water quality degradation and sediment accumulation. In severe cases, this "self pollution" can overload the capacity of the local environment to provide inputs (such as dissolved oxygen) and assimilate wastes, contributing to fish disease outbreaks and undermining sustainability.

PROSPECTS

Hatchery production of groupers is expanding rapidly in Asia. Recent improvements in hatchery production technology have resulted in an overall increase in the survival of grouper larvae in hatcheries, which has led to increased commercial hatchery production of several species, particularly orange-spotted grouper, brown-marbled grouper, and giant grouper. Consequently, availability of hatchery-reared fingerlings is expected to increase in the future, although the selection of species may remain limited. There is little prospect for large-scale hatchery production of the high-value LRFF species, such as the coralgroupers or the threatened humphead wrasse, in the short term.

The problems associated with the use of trash fish as feed are being overcome to a certain extent through the increasing use of pelleted compounded diets. Although pellet diets still utilize comparatively high proportions of aquatic resources (typically 2–3 kg of fisheries product inputs for each 1 kg of cultured product),[203] these are better than the typical input ratios for trash fish (usually 5–10:1). In addition, up to 80% of the fish protein sources can be replaced by terrestrial protein, such as meat and blood meals derived from abattoir byproducts.[204] Further, the food conversion

[202] Phillips 1998.
[203] Tacon and Barg 1998.
[204] Millamena and Golez 2001; Millamena 2002.

ratios of pellet diets (usually 1.2–1.8:1) are dramatically better than those of trash fish and so the relative cost of pellet diets is often comparable, or lower than, the cost of trash fish required to produce the same biomass of fish—a factor not yet appreciated by many farmers.

Commercial feed companies in Indonesia and the Philippines are now testing specialized grouper feeds. However, because of the farmer acceptance issues for compounded feeds listed above, trash fish will continue to be a major feed source for marine finfish aquaculture in the region for the immediate future.

Some fish health concerns in the trade have been addressed through groups focusing on general issues. The (inter-governmental) Network of Aquaculture Centers in Asia-Pacific produced the "Asia Regional Technical Guidelines on Health Management for the Responsible Movement of Live Aquatic Animals," which provides guidelines for reducing risks associated with transboundary movements.[205] The Southeast Asian Fisheries Development Center's Aquaculture Department developed a practical grouper health manual[206] that provides guidance on hatchery and farm health management, and is available in English, Tagalog (Philippines), Indonesian, Thai, Mandarin, and Vietnamese.

There is increasing appreciation of the environmental impact of marine finfish culture in Southeast Asia, partly because of the worldwide focus on the environmental impact of Atlantic salmon farming and unregulated shrimp culture. In some countries, there is a lack of legislative frameworks and enforcement. Problems can be addressed by more emphasis on local planning and co-management (government-industry), and zoning of coastal areas for marine fish farming as has been done in Hong Kong, China—although critics argue that the present zoning there is inadequate.[207] Such zoning has to be accompanied by control measures that limit farm numbers (or fish output, or feed inputs) to ensure that effluent loads remain within the capacity of the environment to assimilate wastes.[208]

[205] FAO/NACA 2000.
[206] APEC/SEAFDEC 2001.
[207] Lai 2002; Sadovy and Lau 2002.
[208] Phillips 1998.

Increasing market demand for groupers with assured quality (and food safety), produced using environmentally sound farming practices, will provide further incentives for LRFF farmers to adopt improved environmental management practices. A voluntary set of standards is being prepared for the region as part of the standardization project mentioned in Chapter 5.

A recent development in the Pacific and in the Caribbean is the use of light traps and special nets to harvest the larvae or fry of fish and invertebrates before they settle onto the reef, for subsequent grow-out.[209] At this stage these pre-settlement fish are subject to extremely high mortality, such that harvesting a proportion of them should have negligible impact on adult fish populations.[210] In contrast, the natural mortality of settled fingerlings may be relatively low and the fisheries for these larger fingerlings may be subject to the same harvesting constraints as fisheries for adult fish.[211] However, catches using the new techniques vary substantially seasonally and between sites. While some species of value to the LRFF trade are caught at some sites at various times, the techniques appear to show most promise for the capture of high-value aquarium fish and invertebrates.[212]

There has been significant interest in enhancement of grouper populations by seeding reefs with hatchery-reared fish. The studies that have been carried out range from short-term survival experiments[213] to long-term stocking of leopard coralgrouper in Japan. Although some releases of groupers have been monitored for their short-term survival[214] and ecological adaptation,[215] there has been little assessment done of the impact of stocking on wild populations or of the appropriate times and places for releases into the wild. Population enhancement of groupers, like that of other marine finfish, needs to be undertaken using a "responsible approach"[216] that provides a framework for assessing a range of potential impact, including ecological, genetic, and disease issues.

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[209] Dufour 2002; Hair et al. 200; Watson et al. 2002.
[210] Doherty 1991; Sadovy and Pet 1998.
[211] Sadovy and Pet 1998.
[212] Hair et al. 2002.
[213] Roberts et al. 1995.
[214] e.g., Roberts et al. 1995; Uwate and Shams 1997.
[215] e.g., Kayano 2001.
[216] Blankenship and Leber 1995.

Unfortunately, restocking has often been used as an alternative to fisheries management. Restocking should only be used to complement, not replace, management of fisheries resources.

The genetic consequences of restocking are important. Given that there is potential for some high-value grouper species to become rare in the wild, hatchery populations may become important sources of genetic material for these remnant populations. Were this to occur, it would be important to manage the captive stocks to ensure the retention of maximum genetic diversity. Maintenance of fish stocks in hatcheries can result in decreased genetic diversity due to small founder populations and inbreeding effects if hatchery-reared fish are retained for future use as broodstock.[217]

The challenge remains to undertake marine finfish farming within a sustainability framework that incorporates a range of measures to reduce environmental impact while simultaneously providing socioeconomic benefits. One proposed framework[218] comprises four core stages: analysis, knowledge, constituency-building, and action, drawing on case-study experiences with coastal communities, and attempts to discourage destructive fishing practices and to encourage sustainable livelihoods through aquaculture. Market incentives, perhaps associated with the adoption of live reef fish standards and possible eco-labeling schemes, will also have an influence on the future development of marine finfish farming that targets live fish markets.

[217] Allendorf and Ryman 1987.
[218] Haylor et al. 2003.

7 INSTITUTIONAL ASPECTS

The countries and territories affected by the LRFF trade are mainly those with extensive coral reefs, where a major source of protein for coastal communities is reef-associated fishes and invertebrates, and ecotourism is viewed as an important economic activity. Ecotourism is particularly important in some Pacific island countries and parts of Southeast Asia where opportunities for economic growth and employment are few. Ecotourism potential depends on maintaining the quality of the coral reefs. Thus, reef conservation is vital not only as a key to income from tourism but also for food security of the communities themselves.

Understandably, the high-value nature of the LRFF trade has attracted much interest in the Indo-Pacific region. However, as discussed in Chapter 5, few, if any of these countries have any sound management practices. Indeed, most of the countries do not have the capacity or financial resources to implement effective fisheries management plans.

Past approaches to addressing concerns in the LRFF trade in the Pacific island countries through external assistance have been characterized as ad hoc and short term, with inadequate training of local personnel and sometimes flawed methods, and lacking in coordination. The result has been conflict of interests, duplication of effort, and wasted resources.

Cooperation among such countries to share experiences, and to seek help jointly in managing their LRFF fisheries is a cost-effective and efficient approach. There is already an excellent track record of such cooperation in the Pacific island countries in managing their highly valuable migratory tuna resources. Although there has been little formal cooperation to date among producer countries in dealing with the LRFF trade, there has been positive action among the Pacific island countries, while Australia, which has a long, if mixed, record of fisheries management, has already put in place measures to regulate its LRFF trade. There is little cooperation among countries in Southeast Asia in respect of the LRFF trade.

EXISTING INSTITUTIONS

Pacific Regional LRFT Initiative

Of the eight intergovernmental organizations in the Pacific island countries, two have been involved in the LRFF trade: the Secretariat of the Pacific Community (SPC), which has been addressing issues concerned with the LRFF trade; and the Forum Fisheries Agency, which has provided funding.

The 22 countries of the SPC requested the SPC in 1998 to work toward sustainable LRFF fisheries. The subsequent action by the SPC was called The Pacific Regional LRFT Initiative. The Initiative has the primary objective of providing technical assistance and support, where required, in order to establish sound policies, strategies, and management plans; develop the capacity in these countries to sustainably implement these policies, strategies, and plans; and strengthen regional cooperation among these countries on the sustainable management of live reef resources.

In 1999, the SPC signed a memorandum of understanding with three nongovernment organizations—The Nature Conservancy, the International Marinelife Alliance, and the World Resources Institute—to work together in addressing LRFF trade concerns.

As of mid-2003, the achievements of the Initiative have been

- assessments of the resources in four countries (the Fiji Islands, Kiribati, Tonga, and Vanuatu);
- management guidelines for two countries (the Fiji Islands and Kiribati);
- assistance in developing management plans for the Solomon Islands and Papua New Guinea;
- information material, including texts, a video, waterproof fish identification cards, and a poster of the main fish species of concern;
- a training workshop on visual assessment of LRFF species and a regional workshop on current issues and problems; and

- ongoing advice to three countries (Kiribati, Papua New Guinea, and Tonga) on managing the industry.[219]

The Initiative has been supported by the Asian Development Bank (through regional technical assistance), the Australian Centre for International Agricultural Research (in the Solomon Islands), the United States Agency for International Development (through The Nature Conservancy), and the Government of Taipei,China (for a review of the trade). Private donors have included the MacArthur Foundation, the David and Lucille Packard Foundation, and the Oak Foundation.

Regional/International Organizations

Apart from the International Marinelife Alliance, The Nature Conservancy, and the World Resources Institute, which are nongovernment organizations that have been working directly with the SPC, the following groups have interests in the LRFF trade:

- Asia-Pacific Economic Cooperation (APEC) group, which includes a few representatives from the Pacific Islands and also the major consumer economies in Southeast Asia. Two working groups of APEC are relevant to the LRFF trade: Fisheries, and Marine Resource Conservation. Both have addressed issues relating to the international trade in live fish and to mariculture.

- Asia-Pacific Fishery Commission (APFIC), an FAO body established in 1948, which functions to promote full and proper utilization of living aquatic resources by developing and managing fishing and culture operations and related activities. It is not clear whether APFIC has done anything in relation to the LRFF trade, but the membership includes all major consumer countries so a potential role is apparent.

[219] Secretariat of the Pacific Community 2002; Yeeting, 1999a, 1999b, 2000, 2002a, 2002b, in press; Yeeting, Labrosse, and Adams 2001.

- Hong Kong Chamber of Seafood Merchants, established in 1997, which represents the live seafood industry to the Government;

- Marine Aquarium Council, a new US-based private group that promotes conservation of marine resources;

- Network of Aquaculture Centers in Asia-Pacific, an intergovernment group that aims, inter alia, to improve grouper culture and has produced technical guidelines on fish health management in the trade;

- Society for the Conservation of Reef Fish Aggregations, established in 2000, which specifically promotes the protection and management of spawning aggregations;

- TRAFFIC, the wildlife trade monitoring network founded in the 1970s to assist in implementing the Convention on International Trade in Endangered Species (CITES), by addressing issues related to documentation and practical control and management of international trade in threatened species; and

- World Wildlife Fund, especially its Hong Kong, China office, which has been undertaking local public awareness activities.

FUTURE REGIONAL COOPERATION

The Pacific Regional LRFT Initiative has demonstrated the benefits of a coordinated approach to the LRFF trade. It would be clearly desirable to extend such cooperation and coordination to other producing countries. Such linkages could lead to uniformity in collection of production data; awareness of the problems and prospects in each country; and pooling of resources for further development of assessment, management, and monitoring the LRFF fisheries, as well as for training personnel in these aspects.

Involvement of representatives of the fishers, brokers, importers, and others in the trade would be important in seeking

ways of arriving at a mutually agreeable basis for sustainable trade in LRFF.

Meanwhile, independent assistance efforts continue, even within the SPC group. Most Pacific island countries tend to accept any assistance available. Thus, overlap and resource waste continue to some extent. However, such activities at least help create awareness of the problems and of ways to obtain sustainable benefits from the LRFF trade.

Some other activities that a regional approach would facilitate include

- maintaining a registry of companies and vessels involved in the trade, for the purpose of sharing information about "good" and "bad" players and possibly for blacklisting bad players;

- developing a centralized vessel monitoring system, in which transport and supply boats are required to carry and continually operate position transmitters. In order to cope with the possibility of poaching in remote areas, the cooperative agreement underpinning the system would have to include key parties on the market side. Only then would there be the possibility of ensuring that all vessels involved in the industry are subject to the monitoring requirements;

- research into optimizing the benefits from the resources without depleting them, for the sustained benefit of the resource owners; and

- developing alternative forms of livelihood that do not create additional pressure on the marine resources.

ROLE OF REGIONAL/INTERNATIONAL DONOR ORGANIZATIONS

In part, the independent assistance projects in various LRFF trade countries exist because there has been little donor coordination or consultation concerning the trade. Given the

problems that have arisen in duplication, conflict of interests, and wasted resources, there is the same need for coordination among donors as there is for coordination among the countries concerned. In the LRFF trade, there is much to be gained by supporting regional rather than individual-country activities.

The continuing boom-and-bust nature of LRFF fisheries, the present inability of most countries to implement management measures effectively, and the cost of improving national capacity suggest that aquaculture, rather than fishery, should be the focus of future attention in some countries— subject to the necessary controls and considerations (see Chapter 6). Feasibility studies are needed across the region to determine where aquaculture really makes sense, ecologically and economically. For that subgroup of producing countries, a number of areas of research in aquaculture technology need to be addressed. Concurrently, programs of awareness and training for coastal communities could be mounted. Along the trade chain from fishing companies to consumers, there is a need to promote hatchery-reared rather than wild-caught fish.

All these endeavors would benefit from a regional approach, to both collate and distill experiences and recommendations from individual countries, and avoid duplication of effort, especially important given the relatively small size of the trade. Most LRFF-producing countries cannot afford by themselves to assist coastal communities to take advantage of the LRFF. A set of activities emanating from a regional body of all stakeholders should be the basis for future involvement of regional or international assistance agencies, rather than assisting individual countries.

Appendixes

Appendix 1: Conventional Management Tools and the LRFF Trade

Management Tool	Merit	Impediments
Output Controls		
Minimum/maximum sizes	➢ Limiting the size at which fish can be caught can – increase/ maintain spawning biomass (i.e.. ensure sufficient fish reach spawning size before capture); – address management considerations resulting from sex change in fish; and – address the problem of growth overfishing. ➢ Size limits can be based on known patterns of sexual maturity in other geographic locations.	➢ Effective management of coral reef fisheries on the basis of minimum and maximum size limits for target and nontarget species is hindered by – limited availability of biological data; – physical remoteness of landing sites; – discord between minimum sizes based on biological data, and preferred market size; – need for collaboration between industry and government agencies.
Catch quotas	➢ Catch quotas help to maintain catches within sustainable levels and allow catches to be allocated among different fishery sectors. ➢ Catch quotas can specify catch volumes for certain species.	➢ Setting quotas in tropical inshore multispecies fisheries is resource intensive and hindered by – limited knowledge of the biology and stock size of targeted species; – the need to monitor local and export catches of artisanal and LRFF fisheries concurrently; – multiple landing points; – poor information, with data aggregated into species groups rather than by individual species; – localized overfishing due to effort concentration in inshore areas and areas close to trading hubs; – decentralized and subnational implementation;- high management and enforcement costs; and – highly variable seasonal stock abundance.
Export controls	➢ National export bans can be strengthened through international trade regulations (i.e., CITES) that prohibit or regulate the harvest and sale of threatened or endangered species.	➢ The large number of geographically remote fishing sites and a lack of centralized landing sites in many live reef fisheries hinder monitoring of exports and make enforcement difficult.

Appendix 1: Conventional Management Tools and the LRFF Trade *(cont'd.)*

Management Tool	Merit	Impediments
Area closures (marine protected areas and no-take zones)	➢ There is potential for positive spillover effects from areas closed to fishing to those remaining open.	➢ Capacity constraints limit the effective enforcement of spatial closures at remote sites.
	➢ Zones/reefs can be closed for extended periods to act as harvest refugia and replenishment areas for recovery of fish stocks.	➢ High management and enforcement and compliance costs may be involved.
Seasonal closures (spawning aggregations)	➢ Protection of spawning aggregation sites and migration routes to and from these sites during the spawning season protects spawning fish and reproductive output.	
	➢ Protection of species vulnerable to overfishing because of their spawning times; reduces high mortality often associated with catching of ripe males and females.	➢ Targeting of spawning aggregations is driven by the need to collect sufficient fish for sea transport in a short time period.
Input Controls		
Licensing		
	➢ Licensing can compel operators to submit regular data that are useful for evaluating the state of the fishery, or other information considered necessary. Licenses can – limit the time period over which the license is active; – nominate the species able to be retained for live export or excluded from being exported;	➢ The prospect of implementing and maintaining a license program for many hundreds of artisanal fishers is limited.

(continue next page)

Appendix 1: Conventional Management Tools and the LRFF Trade *(cont'd.)*

Management Tool	Merit	Impediments
Licensing (cont'd.)	– limit the amount of effort being applied to certain reefs (e.g., vessel numbers, area closures); – impose moratoriums; – designate permitted mode of transport; – set out ownership and local crewing requirements of live fish operations; and – control transshipments of live fish and designate live fish collection areas. ➢ Licensing can recognize traditional reef ownership (e.g., customary marine tenure). ➢ While enforcement capacity will dictate a licensing program's effectiveness, institutional capacity requirements are less than for output controls.	
Gear controls	➢ Specifying permissible gear, such as minimum hook sizes, can increase the size/age at which fish are recruited to the fishery and protect juveniles. ➢ Prohibiting certain gears and fishing practices will reduce mortality of target species, reduce bycatch, and protect habitat and standing biomass.	➢ Effective and widespread adoption of nondestructive capture techniques will be hindered by – overexploited target stocks and declining catch per effort, which lead to unsustainable fishing practices; – limited enforcement capacity because of physical remoteness of landing sites; – accuracy and timing of procedures to detect poisons (e.g., cyanide); and – the efficiency of destructive practices relative to less destructive alternatives, which makes the former more attractive.

Appendix 1: Conventional Management Tools and the LRFF Trade *(cont'd.)*

Management Tool	Merit	Impediments
Trial fishing/moratoriums	➢ Trial fishing periods can be used to collect biological and catch and effort information and evaluate the effects of LRFF fisheries on other fisheries, particularly subsistence fishing. ➢ Moratoriums or periodic closures can limit fishing effort or close a fishery based on "trigger points," such as number of days fished or the volume caught. ➢ Limit LRFF fisheries to designated areas during the trial period to improve effectiveness of and minimize resource requirements for monitoring.	➢ An effective observer monitoring program is needed, which will be limited by: – capacity and resource constraints; – observer knowledge; – corruption; and – enforcement capability.
Mode of transport (air/sea)	➢ Restrictions on sea transport can – decrease rates of mortality, thereby increasing shipment values; and – enhance monitoring and enforcement efforts.	➢ Adoption of air transport may be hindered or excluded by – lack of air transport options at geographically remote landing sites; and – distance of remote fishing sites from market.

8 CONCLUSION AND RECOMMENDATIONS

CONCLUSIONS

An Elusive Trade

The LRFF trade remains an elusive industry. Estimates of total production and the contribution of aquaculture to the trade vary widely. Government import data in Hong Kong, China are the main window on the trade, but they are admittedly underestimates to a still unknown degree; and they have been refined to show most species imported only from 1999.

Any conclusions that can be made about the size of and trends in the trade will be superficial until long-term and comprehensive data become available, not only for Hong Kong, China imports, but also for other importing countries, domestic trade, and for the source countries, for which export figures are often nonexistent, inaccurate, or incomplete. One thing is clear, however. Should the market in mainland PRC expand significantly, as predicted, the pressure on LRFF fisheries is expected to increase enormously.

Improvements in data collection are not likely to come quickly, given the size of other problems—ranging from general overfishing, to illegal fishing, to inadequate infrastructure, funds, and personnel to deal with these and other management issues—facing national fisheries authorities in many source countries around the region, particularly in Southeast Asia.

Part of both the mystique and the challenge of the LRFF trade has been its luxury nature; rarity and localized depletions of target fish populations will not necessarily lead to cessation in their trade. Consumers are willing to pay very high prices for these fish. Unless awareness programs can quench this desire to consume rare wild animals, the fisheries will continue until the last of the desired fish are gone—perhaps irreversibly.

However, consumers cannot always distinguish wild from cultured fish. Advertizing the qualities of cultured LRFF in retail outlets—for example, the absence of any threat of poisoning—could

well turn the tide in favor of cultured fish as well as discourage the capture from the wild of vulnerable species that can be cultured.

Trade Benefits Vary Widely

The benefit of the trade to fishers varies widely across countries. In some, the value added—the difference in selling price between live and dead reef food fish—is so great that it is easy to understand the incentives for overfishing to a high degree, for using illegal fishing methods, and for continuing to fish even when the target fish become rare.

However, the real nature of the value added to this often boom-and-bust fishery cannot be judged in terms of economics alone, or merely over the short "boom" period, especially if, associated with its operation, local fish populations are depleted, there is social inequity or conflict, and divers are injured or killed. Value adding must take into account the suite of changes and both positive and negative impact of the fishery in the longer term. There is a need for detailed and realistic socioeconomic analyses, factoring in both resource limitations and potential long-term ecological consequences as well as costs of and the challenge of effective management.

LRFF Catches Far Exceed Sustainable Levels

Biological knowledge of LRFF species in general and groupers, the main species in the trade, in particular is poor. The most basic need—to know how much can be taken each year sustainably—is almost completely lacking for many species. The present conclusions are based on various assumptions in analyses of the trade and of resource productivity, but it is believed that these provide a realistic starting point for future refinement.

Assessments to date of potential yields (catch per unit area per year) of LRFF groupers are vague, centered around a regionwide annual average yield for reefs in good condition of 0.5 t per km^2 per year for all types of fishery, including those for both live and dead fish. The present average regional yield of LRFF, 0.6 t per km^2 per year, may already be at a level of concern, because much of Southeast Asia's reefs, which account for the majority of grouper production, are not in good condition. Importantly,

because the fisheries for live fish cover only a fraction of the Indo-Pacific region, the compelling conclusion is that the levels of catches in these fisheries far exceed what is sustainable.

While the trading base of LRFF fisheries may be stable in a country for many years, the fishing grounds are constantly shifting, possibly representing, in combination with subsistence and other small-scale fishing for the same species, overfishing to a degree only paralleled by other boom-and-bust fisheries, such a those for trochus and sea cucumber.

Increases in the present yields of high-value LRFF species from the wild are unlikely, because of biological constraints on total grouper production. Thus, there are three options to increase production: finding new sources, diverting subsistence to live export, or further supplementing wild-caught with hatchery-reared fish. In terms of the first, traders constantly seek new sources, increasingly distant from most demand centers. However, continuing depressed prices over the last 4–5 years mean that transporting fish to market from these more remote locations may not be financially viable, especially in the case of the medium-priced groupers that tend to dominate in these areas. Many subsistence or small-scale local fisheries are heavily exploited and careful decisions must be made regarding the best social and economic use of fish that are also desired in the live fish trade; however, there is typically little management of such fisheries and adjustments in allocation may not be possible in practice. An increase in hatchery production probably carries more hope but is subject to a suite of problems (discussed below) that suggest it can never completely supplant wild sources.

LRFF Fisheries, to be Sustainable, should be Small Scale and Closely Managed

Most countries in the region do not yet have in place the policies or controls needed to deal adequately with the aggressive and intensive nature of LRFF fisheries. In some countries and areas, the capacity to manage a LRFF fishery is so limited and the prospects for strengthening that capacity are so bleak that at least in the near future, the only realistic management objectives are to minimize habitat degradation and fish stock depletion. In those cases, it is not a matter of determining whether a LRFF fishery is a

good option, but rather merely coping with it. Emphasis would continue to be on curbing the use of cyanide; discouraging compressor diving, which is associated with cyanide use, overfishing, and accidents; stopping the export of especially vulnerable species; implementing trade and resource monitoring programs; and safeguarding at least a few areas from fishing, particularly areas that include spawning aggregation sites.

But is an extensive management regime practical? Although there are clearly wide variations in the amount of LRFF supported by reefs, according to, for example, reef size, habitat type, and reef condition, the sustainable amount on all reefs is negligibly small. The average attainable yield of 0.5 t per km^2 for all types of grouper fisheries, for example, means an average of 500 1-kg fish per year (less than 2 fish a day!) per km^2 of reef area. Managing a LRFF fishery that small could not be cost effective (and the existing commercial and subsistence reef fisheries would at least have to be monitored), even if efficient and fully effective measures were available and enforceable.

A management regime might also have to consider the pressures on resources from demand for fish feed and coastal waters for holding or grow-out of fish. Overall, these different activities would be vying for a profitable share of a small resource under intense pressure.

Simple "data-less" approaches may be, in practice, the most appropriate ways and the only tools needed to control LRFF fisheries; indeed to control reef fish fisheries in general. Examples include permanent closure of a significant part of the total reef area and export controls. In the case of a protected area approach, which in essence is risk-based, the integrity of some reefs is given up to the fishery while those considered more critical are conserved, with the knowledge that the fishery may move on after a few seasons. Of course, it is highly desirable to prevent LRFF fishers from using such destructive techniques as cyanide and to stop them breaking apart the coral in their quest for target fish, but recent history suggests that this is hardly possible. From the point of view of conserving reef ecosystems, a safer approach would be to reverse the standard approach of closing certain areas to (LRFF) fisheries, and instead consider all areas closed except for designated fishing zones.

Controls on exports, while not quantitatively linked to resources available, recognize that reef resources in general cannot withstand the high rates of exploitation often engendered in export fisheries, and assign realistic value to their local use in trade and consumption.

The issue of enforcement could be addressed through cooperation between a country's fisheries/agriculture department and its navy or coastguard. Although marine resources are major parts of the economies of many Indo-Pacific nations, the general availability of funds suggests that it may be more logical to support extra naval or coastguard patrols (both by air and sea) than to undertake surveys and fine-tune regulations that, like most other fisheries regulations, would be unenforceable and of little use when the fishery moves on. An aggressive stance, such as through the presence of patrol vessels, that is well known to the players in the industry, could become a major "management" measure to ensure the integrity of the bulk of a country's marine resources.

The overall conclusion, however, is that LRFF fisheries, as currently practiced, are highly undesirable to most source countries from all points of view—ecological, economic, health, and social—unless strictly controlled, as in the case of Australia. The evidence strongly implies that to be sustainable, an LRFF fishery has to operate on a very small scale and be closely managed. A risk-averse country or community would be wise to protect its communities and reef resources by preventing an LRFF fishery from starting and keeping reef resources for local use.

Aquaculture Offers Great Prospects, Many Challenges

Aquaculture, in the wider sense, has always played a large part in the LRFF trade. However, there has been misplaced optimism about aquaculture at least as it is currently practiced in the region as a means of avoiding the overfishing of wild fish populations. The majority of present culture operations rely on catching seed—the very small fish—and other bigger but less than market-size fish, mainly groupers, from reefs, thus adding to rather than subtracting from fishing pressure on the fish populations. And most grouper grow-out continues to depend on large amounts of other wild-caught fish for fish feed. Moreover, it is only possible to culture a very few of the species preferred in the trade; much

greater diversity in hatchery reared species is necessary if aquaculture is to replace a significant wild-caught component.

The large numbers of LRFF produced annually from grow-out of wild-caught sub-market-size fish represent an invisible and unquantified element of the overall present LRFF catch. If it is not taken into account somehow, it could make management measures for all grouper fisheries hopelessly optimistic. From the rough estimates that can be made, the contribution of these fish to total live grouper production is greater than that of wild-caught market-size groupers. In such cases as the threatened humphead wrasse, although several countries protect the species, they inexplicably have exemptions for grow-out culture of juveniles, which will further exacerbate its heavily exploited state.

The aquaculture subsector could expand until profit levels become marginal, given the opportunity costs of labor in many countries in the Indo-Pacific region. Such expansion would depend in part on growth in LRFF markets, both local and export, while in the case of grow-out operations, it also depends on the source of young fish—an expanding fishery for wild-caught juvenile fish would, before it collapsed, cause long-term damage to the adult populations, with flow-on effects in other fisheries and the reef ecosystems.

Even sustainable (hatchery-based) aquaculture will provide only a restricted range of species to live fish markets, both because of farmers' preferences in their choice of species—related in part to grow-out times—and technological problems in hatchery development of some high-value species. Large-scale aquaculture may also lead to localized environmental impact, particularly where wild fish are used as the feed source, and the high demand for such fish feed continues to cause concern. Nevertheless, it seems certain that as the industry matures, there will be increasing reliance on hatchery-reared broodstock and, in the longer term, selective breeding programs for such traits as faster growth, and pelleted feeds that require less wild fish.

Most importantly, if cultured fish become a larger proportion of the LRFF market, hatchery-based aquaculture holds the prospect of increasingly involving and benefiting coastal communities as grow-out farmers. The challenge remains to foster sustainable LRFF farming and take measures to reduce environmental impact while simultaneously providing socioeconomic benefits.

Regional Cooperation would be Advantageous to all Stakeholders

Regional cooperation among Pacific-island producing countries in the LRFF trade has provided some initial management recommendations. Such cooperation needs to be extended to all producing countries so that a greater body of expertise and experience can be brought to bear on important issues and mutually agreeable solutions be considered. Such an initiative is particularly important because there are no regional management authorities that deal with reef fisheries in general, and the LRFF trade in particular. Involvement of representatives of the chain of trade—fishing companies, brokers, importers, etc.—is necessary to ensure that all stakeholders have a voice and take part in making decisions that affect them; otherwise they may not respect such decisions.

The role of assistance agencies should be primarily at the regional level. Research, training, and most other activities at this level can benefit all the producing countries because the same target fish, by and large, are found throughout the region. A new focus is suggested: assisting the trade to move toward hatchery-based aquaculture in those countries where it is feasible, rather than continuing to focus on the fishery per se.

RECOMMENDATIONS

The statements and conclusions above point to many areas where research and/or surveys could help countries in the Indo-Pacific region make decisions on how to use their reef fish resources to best advantage and determine what additional information may be needed for this purpose. In fact, the LRFF trade provides an ideal impetus—a wake-up call—for these countries to look at how best to use and sustain not only their reef fish resources, but also their entire reef ecosystems. Some ways to accomplish this joint goal follow.

Trade data. Monitoring the centers of production and export (or re-export) is needed to improve coverage of both fisheries and culture operations, preferably in a manner compatible with the Hong Kong, China commodity codes for live reef fish; on a regional basis, collation of national data and feedback to all concerned countries is a minimum requirement, possibly in collaboration with FAO to ensure there is no double counting from the different fisheries. Other information that would help to regulate the trade includes a registry of vessels and a vessel monitoring system.

Economic analyses. Analyses of the economic benefits and costs of all aspects of the trade in the long and short terms, including aquaculture components based on current and projected practices, are needed to examine the monetary advantages to exporting and importing countries within different time frames and sets of assumptions. Economic analyses, especially those that explore long-term scenarios, must factor in the reality that most of these fisheries are not managed, could be operating unsustainably, and may well compromise local (nonexport) fisheries.

Trade standards, outreach, and awareness. LRFF industry standards and best practices being developed to improve the conduct of the industry will provide a guiding mechanism that each country should adapt, based on its own management objectives, resources, and capacities. Implementation through legislation should be in close cooperation with source and demand country governments and through multilateral forums such as APEC. Outreach campaigns aimed at all industry stakeholders, including LRFF consumers, are needed to raise awareness of the adverse impact associated with the trade and to influence consumer eating habits. Such campaigns could promote sustainable aquaculture as an alternative source and discourage the purchase of threatened or vulnerable species.

Regional trade organization. An organization that includes all stakeholders in the LRFF trade could act as both a guiding force and watchdog on the industry. Regional and international donor

organizations would have a role in supporting the recommendations of such an organization, and close coordination with source countries would be needed to ensure that initiatives are properly developed.

Fisheries Resources

Population dynamics of target species. Knowing how many fish are available for capture without depleting the resource is a basic need. It is particularly important when different subsectors are exploiting the same resource, in this case, LRFF fisheries and subsistence and commercial reef fisheries.

Spawning aggregations and threatened/vulnerable species. Spawning aggregations and threatened or vulnerable species should not be exploited in the LRFF trade.

Training. Training programs for fishing communities are needed on maintaining reef ecosystems and sustainable fishing, appropriate (nondestructive) fishing practices, and handling methods to reduce fish deaths.

Aquaculture

Development of sustainable aquaculture. Donor assistance could be directed at further exploring the potential for sustainable full-cycle aquaculture, which shows promise of sustainable benefits for coastal communities in some countries, through feasibility studies, technology development, and training programs.

Fisheries Management

Alternative management measures. Modeling of standard and innovative approaches would help countries to make informed management choices with regard to developing LRFF fisheries and other resource uses. One example would be to limit live fish fisheries to certain areas on a trial basis and monitor the outcome, building on the results. Another might be to limit the ports of export or import to ensure a tighter control on international trade in live fish.

The Bigger Picture

Ecosystem analysis. A major unknown factor is the relationship of LRFF fish, especially groupers, with other components of the reef ecosystem. Analyses of what drives ecosystem production and maintains its stability should be undertaken—the software is available—to learn the short- and long-term effects not only of LRFF fisheries, but also of other reef fisheries.

Economic benefits of coral reefs. Urgently needed are studies of the relative economic benefits to fishing communities, resource owners, fishing companies, and countries of starting or maintaining LRFF fisheries vis-à-vis existing commercial and subsistence fisheries and alternative resource uses, particularly (eco) tourism.

Participatory management. Reef owners and fishing communities should be involved in the management of their reef resources—not only LRFF but also all other resources, especially other high-value trade commodities, such as pearl shell, sea cucumber, and trochus. Helping these people and communities to understand better their reef resources and the significance of these resources both to local and foreign interests, would assist them to make informed decisions on how best to use the resources into the foreseeable future.

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Appendixes

Appendix 1: Conventional Management Tools and the LRFF Trade

Management Tool	Merit	Impediments
Output Controls		
Minimum/maximum sizes	➢ Limiting the size at which fish can be caught can – increase/ maintain spawning biomass (i.e.. ensure sufficient fish reach spawning size before capture); – address management considerations resulting from sex change in fish; and – address the problem of growth overfishing. ➢ Size limits can be based on known patterns of sexual maturity in other geographic locations.	➢ Effective management of coral reef fisheries on the basis of minimum and maximum size limits for target and nontarget species is hindered by – limited availability of biological data; – physical remoteness of landing sites; – discord between minimum sizes based on biological data, and preferred market size; – need for collaboration between industry and government agencies.
Catch quotas	➢ Catch quotas help to maintain catches within sustainable levels and allow catches to be allocated among different fishery sectors. ➢ Catch quotas can specify catch volumes for certain species.	➢ Setting quotas in tropical inshore multispecies fisheries is resource intensive and hindered by – limited knowledge of the biology and stock size of targeted species; – the need to monitor local and export catches of artisanal and LRFF fisheries concurrently; – multiple landing points; – poor information, with data aggregated into species groups rather than by individual species; – localized overfishing due to effort concentration in inshore areas and areas close to trading hubs; – decentralized and subnational implementation;- high management and enforcement costs; and – highly variable seasonal stock abundance.
Export controls	➢ National export bans can be strengthened through international trade regulations (i.e., CITES) that prohibit or regulate the harvest and sale of threatened or endangered species.	➢ The large number of geographically remote fishing sites and a lack of centralized landing sites in many live reef fisheries hinder monitoring of exports and make enforcement difficult.

Appendix 1: Conventional Management Tools and the LRFF Trade *(cont'd.)*

Management Tool	Merit	Impediments
Area closures (marine protected areas and no-take zones)	➢ There is potential for positive spillover effects from areas closed to fishing to those remaining open.	➢ Capacity constraints limit the effective enforcement of spatial closures at remote sites.
	➢ Zones/reefs can be closed for extended periods to act as harvest refugia and replenishment areas for recovery of fish stocks.	➢ High management and enforcement and compliance costs may be involved.
Seasonal closures (spawning aggregations)	➢ Protection of spawning aggregation sites and migration routes to and from these sites during the spawning season protects spawning fish and reproductive output.	
	➢ Protection of species vulnerable to overfishing because of their spawning times; reduces high mortality often associated with catching of ripe males and females.	➢ Targeting of spawning aggregations is driven by the need to collect sufficient fish for sea transport in a short time period.
Input Controls		
Licensing		
	➢ Licensing can compel operators to submit regular data that are useful for evaluating the state of the fishery, or other information considered necessary. Licenses can – limit the time period over which the license is active; – nominate the species able to be retained for live export or excluded from being exported;	➢ The prospect of implementing and maintaining a license program for many hundreds of artisanal fishers is limited.

(continue next page)

Appendix 1: Conventional Management Tools and the LRFF Trade *(cont'd.)*

Management Tool	Merit	Impediments
Licensing (cont'd.)	– limit the amount of effort being applied to certain reefs (e.g., vessel numbers, area closures); – impose moratoriums; – designate permitted mode of transport; – set out ownership and local crewing requirements of live fish operations; and – control transshipments of live fish and designate live fish collection areas. ➢ Licensing can recognize traditional reef ownership (e.g., customary marine tenure). ➢ While enforcement capacity will dictate a licensing program's effectiveness, institutional capacity requirements are less than for output controls.	
Gear controls	➢ Specifying permissible gear, such as minimum hook sizes, can increase the size/age at which fish are recruited to the fishery and protect juveniles. ➢ Prohibiting certain gears and fishing practices will reduce mortality of target species, reduce bycatch, and protect habitat and standing biomass.	➢ Effective and widespread adoption of nondestructive capture techniques will be hindered by – overexploited target stocks and declining catch per effort, which lead to unsustainable fishing practices; – limited enforcement capacity because of physical remoteness of landing sites; – accuracy and timing of procedures to detect poisons (e.g., cyanide); and – the efficiency of destructive practices relative to less destructive alternatives, which makes the former more attractive.

Appendix 1: Conventional Management Tools and the LRFF Trade *(cont'd.)*

Management Tool	Merit	Impediments
Trial fishing/moratoriums	➢ Trial fishing periods can be used to collect biological and catch and effort information and evaluate the effects of LRFF fisheries on other fisheries, particularly subsistence fishing. ➢ Moratoriums or periodic closures can limit fishing effort or close a fishery based on "trigger points," such as number of days fished or the volume caught. ➢ Limit LRFF fisheries to designated areas during the trial period to improve effectiveness of and minimize resource requirements for monitoring.	➢ An effective observer monitoring program is needed, which will be limited by: – capacity and resource constraints; – observer knowledge; – corruption; and – enforcement capability.
Mode of transport (air/sea)	➢ Restrictions on sea transport can – decrease rates of mortality, thereby increasing shipment values; and – enhance monitoring and enforcement efforts.	➢ Adoption of air transport may be hindered or excluded by – lack of air transport options at geographically remote landing sites; and – distance of remote fishing sites from market.

Region / Country	Output Controls				Spatial Controls[b]	
	Size Limits	Species Controls	Catch Quotas	Exports Volumes[c]	Area Closure[d]	Seasonal Closures[e]
Southeast Asia						
Hong Kong, China (Imports)						
PRC (imports)						
Indonesia	✓ (HHW)	✓ (KNP)			✓ (KNP)	✓ (KNP)
Philippines	✓[k]	✓[k]				
Malaysia	(HHW in (Palawan)	(HHW in (Palawan)				
Viet Nam					✓ (Palawan)	
Thailand						
Indo-west Pacific						
Australia	✓	✓ (HHW and Humpback Grouper)	✓		✓	✓[l]
Papua New Guinea [m]	✓		✓	✓	✓ (LRFF)	✓
Solomon Islands						
Marshall Islands						
Fiji Islands						
Palau [n]					✓	✓
Indian Ocean						
Seychelles	✓			✓	✓	
Maldives				✓		

DFP = destructive fishing practices; HHW = humphead wrasse; KNP = Komodo National Park.

[a] These controls are not LRFF fishery-specific controls, although some have been specifically employed to protect the resource against the trade.

[b] Spatial controls can be used to protect spawning aggregations through seasonal closures or to provide harvest refugia and replenishment areas for threatened species through permanent area closures.

[c] Export volumes refer to overall controls on a range of species and exclude the banning of certain vulnerable species of fish (e.g., humphead wrasse) from export. These are addressed under species controls.

[d] Unless otherwise denoted (as LRFF), area closures are not specific to the LRFF trade.

[e] Unless otherwise denoted, seasonal closures refer to the protection of known fish aggregation sites during spawning season(s).

[f] Licensing conditions include a) permission to catch, buy or export LRFF; b) restrictions on ownership and operation size; c) area able to be fished and when; d) compensation; e) reporting obligations; and f) export controls, which refer to the licenses granted to foreign vessels to collect and export LRFF. These same licenses generally preclude the foreign vessels from carrying out fishing themselves.

Employed by Countries in the LRFF Trade[a]

Input Controls				Monitoring			Costs
License and Export Controls[f]	Gear Control	DFP Ban[g]	Trial Fishery/ Moratoriums	Effort& Catch[h]	Data Collection Reporting	Transport Mode[i]	Cost Recovery[j]
		✓			✓	Air/Sea	
						Land/Sea	
✓ (a,e,f)		✓			✓	Air/Sea	✓
					(Export data)		(Export tax)
✓		✓		✓	✓ (Export data)	Air/Sea	
						Air/Sea	
						Land/Air/ Sea	
✓	✓	✓		✓	✓ (Export data)	Air only permitted	✓
✓	✓	✓	✓	✓	✓	Air/Sea	✓
✓		✓	✓		✓	Sea	
						Sea	
		✓	✓		✓	Sea	✓
✓ (by species)	✓	✓	✓	✓	✓	Air /Sea	
	✓	✓	✓	✓		Sea	
			✓			Sea	

[g] Destructive fishing includes any or all of cyanide, hookah gear (compressed air diving), blast-fishing, and (coral-weighted) fish traps.

[h] Refers to the collection of effort and catch data from individual fishing operations, excluding exporters.

[i] Transport mode refers to permissible modes of transporting LRFF to markets and includes restrictions on fish collection areas or designated ports.

[j] This refers to payments made to communities, provincial and national governments, and agencies as recognition of resource rent and for improving monitoring and enforcement capacity.

[k] The size limits in Palawan can be circumvented by an exemption that allows for the take of undersized (juvenile) fish for grow-out in cages.

[l] The Coral Reef Finfish Fishery management plan includes three 9-day 'spawning closures' over the whole of the Great Barrier Reef, incorporating 4 days either side of the full moon, for the months of October, November, and December. These months coincide with the known spawning period of *Plectropomus* spp.

[m] Conditions of the trial fishery management plan.

[n] LRFF fishing operations ceased in Palau in 1988 following the government's termination of the fishing company's activities. However, there is no present ban on exporting LRFF.

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