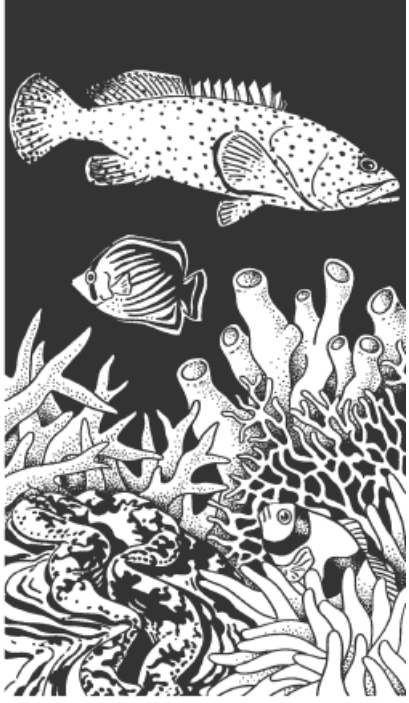

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LIVE REEF FISH
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Inside this issue

Editor:
Tom Graham
PO Box 235
Honolulu
HI 96809
USA
Fax: +1 (808) 625 8755
Email: ThomasRGraham@aol.com

Production:
Information Section,
Marine Resources Division
SPC, BP D5, 98848, Noumea Cedex,
New Caledonia.
Fax: +687 263818
Email: cfpinfo@spc.int
www.spc.int/coastfish

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Editor's note

The following articles read like an atlas of live reef food fisheries, with news from the Indian Ocean and from both sides of the Pacific.

Seychelles: Reporting from the western Indian Ocean, on what was once the edge of the range of the Hong Kong-centred live reef food fish trade, Riaz Aumeeruddy and Jan Robinson describe Seychelles' experience with the trade from 1998–1999. The results of a two-year fishing trial, along with reports of problems in other countries engaged in the trade, led the government to determine that the fishery was not in the best interests of the country, and in 2005, fishing for finfish for the live fish trade was formally prohibited.

United States: Halfway around the world from Seychelles, in California, Scot Lucas provides an update of the US west coast fisheries for live reef food fish. The fisheries do not supply the distant markets of Asia and do not catch the same tropical species or use the same methods as the fisheries in the western Pacific and Indian Oceans, but the challenges faced by fishery managers in all these areas appear to be largely the same.

Papua New Guinea: Richard Hamilton and Manuai Matawai describe the recent development of a fishery for live groupers at the island of Manus, and identify what appears to be a strong relationship between the extraction of fish and the decline of fish numbers at a spawning aggregation site. Their description of the open-close-open pattern of fishery development sounds very familiar.

Australia: In contrast with the often boom-and-bust nature of fisheries for live food fish in much of the Indo-Pacific region, the fishery on the Great Barrier Reef, which predominantly harvests the leopard coralgrouper, has been fairly stable. Martin Russell describes the recent radical makeover of the GBR's fishery management regime, which now includes large areas closed to fishing, limits on total allowable catches, size limits, recreational bag limits and spawning season closures. Based on fish counts at two spawning aggregation sites that have been monitored for 15 years, he tentatively examines the effects of those management changes on fish stocks.

Fiji: Yvonne Sadovy describes field work undertaken to validate information on spawning aggregations provided through interviews with fishers. Ledua Ovasisi recounts the history of Fiji's involvement in the live reef

food fish trade and identifies the challenges facing fishery managers. Yvonne Sadovy and Aisake Batibasaga summarize the deliberations at a recent workshop in Suva aimed at improving the management of the country's reef fish fisheries.

Pacific Islands: Based on case studies in four Pacific Island countries, Mecki Kronen and co-authors examine the social and economic aspects of artisanal reef fish fisheries and explore the relative advantages of alternative paths of commercial fishery development, particularly the option of engaging in the live reef food fish trade.

Tom Graham

PIMRIS is a joint project of 5 international organisations concerned with fisheries and marine resource development in the Pacific Islands region. The project is executed by the Secretariat of the Pacific Community (SPC), the South Pacific Forum Fisheries Agency (FFA), the University of the South Pacific (USP), the South Pacific Applied Geoscience Commission (SOPAC), and the Pacific Regional Environment Programme (SPREP). This bulletin is produced by SPC as part of its commitment to PIMRIS. The aim of PIMRIS is to improve the availability of information on marine resources to users in the region, so as to support their rational development and management. PIMRIS activities include: the active collection, cataloguing and archiving of technical documents, especially ephemera ("grey literature"); evaluation, repackaging and dissemination of information; provision of literature searches, question-and-answer services and bibliographic support; and assistance with the development of in-country reference collections and databases on marine resources.

PIMRIS

Pacific Islands Marine Resources Information System

Closure of the live reef food fish fishery in Seychelles

Riaz Aumeeruddy[1] and Jan Robinson[1]

Introduction

The expansion of the live reef food fish (LRFF) trade — from its original centres in Southeast Asia through much of the western Pacific and parts of the Indian Ocean — has been rapid and dramatic (Johannes and Riepen 1995; Sadovy et al. 2003). In the western Indian Ocean (WIO), poor air links, the long distance to Southeast Asian markets, and lower prices may have restricted the development of LRFF fisheries, with Maldives and Seychelles the only known exporting countries of LRFF in the region (Sadovy et al. 2003). However, while Maldives has a well-established fishery with considerable local involvement, Seychelles has been reluctant to allow further development of the LRFF fishery. This paper describes the evolution of the LRFF fishery in Seychelles, which was largely implemented on an experimental basis (Bentley and Aumeeruddy 1999), and details the factors that led to legislation in 2005 prohibiting the fishing, trade, and export of wild-caught, live finfish, effectively closing the LRFF fishery.

Seychelles is a small island state located south of the equator in the WIO (Fig. 1). It is a large archipelagic nation, comprising 115 islands of small land area (455 km^2) scattered over an exclusive economic zone (EEZ) of close to 1.4 million km^2. A population of about 82,000 resides mainly on the larger granitic islands of Mahé, Praslin and La Digue, while the remaining granitic and coralline islands are sparsely populated. Fishing has traditionally played an important socioeconomic role in the country (Wakeford 2000). Seychelles has one of the highest per capita fish consumption rates in the world at 80 kg yr^{-1} (FAO 2005). Most of the artisanal fisheries catch (typically 4000–4500 tonnes per annum) is consumed locally, and generally less than 10% is exported (Azemia and Robinson 2005), illustrating the importance of these fisheries for food security. Industrial fisheries that target tuna and billfish have developed rapidly since the early 1980s, and the fishing sector now constitutes a major pillar of the economy, contributing close to 40% of the gross receipts for the country in 2004 (Seychelles Fishing Authority 2005).

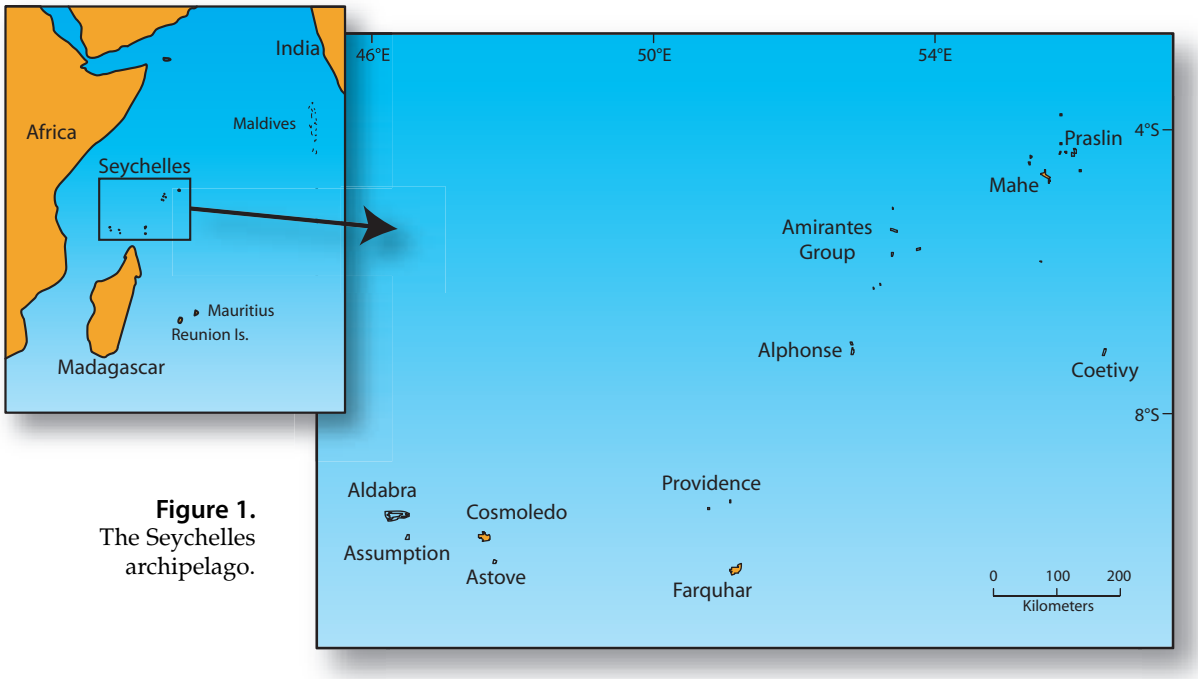

Figure 1. The Seychelles archipelago.

1. Research Section, Seychelles Fishing Authority, PO Box 449, Fishing Port, Mahé, Seychelles. Email: raumeeruddy@sfa.sc

History and operation of the fishery

Live reef food fish were not traditionally fished, marketed or traded in Seychelles. In late 1997, a local fishing company made a request to the Seychelles Fishing Authority (SFA) for permission to fish and export LRFF to Hong Kong (Bentley and Aumeeruddy 1999). While Seychellois fishers and exporters have typically been able to respond to demand from Southeast Asian markets, and have developed local for-export fisheries based on high value products not consumed locally (e.g. shark fins and sea cucumbers), the lack of local expertise in all aspects of this fishery, notably handling and maintaining live fish, ensured that the fishery would require substantial Chinese support. The request was accepted by SFA[2] and the Islands Development Company (IDC)[3] on a trial basis and a fishery operated over two fishing seasons in 1998 and 1999. The fishers, fish handlers and much of the infrastructure were from China. In 1998, the trial was based at Farquhar Atoll (Fig. 1). This fishing ground was chosen to reduce conflicts with traditional artisanal fishers, who rarely fished at Farquhar at that time due to rising operational costs (notably fuel prices) and stagnant local market prices. At Farquhar, the fishing operation was land-based with fishers undertaking daily trips inside the lagoon with small boats powered with outboard engines. The fish were held in 12 floating cages located in the inner lagoon (Fig. 2). The company was allocated an export quota of 40 tonnes (t), which is the amount of fish that IDC was processing annually as salted fish. In 1998, IDC stopped all production of salted fish so as not to conflict with the trial LRFF fishing.

In 1999, due to concerns over sustainability of the fishery at Farquhar (see below), the LRFF fishing company was granted a license to fish at Astove, Assumption, Providence and Cosmoledo. Astove and Assumption were subsequently found to be unsuitable fishing areas because of low catch rates of the target species, and fishing was eventually based entirely at Providence (between February and June 1999) and at Cosmoledo (between October and December 1999) (the gap in operations from June to October was due to mothership engine problems). An export quota of 100 t was a condition of this second license, with a maximum of 25 t allowed to be taken from Providence (Bentley and Aumeeruddy 1999). This condition was applied to Providence because it had the fishing grounds most frequented by traditional artisanal fishers. To monitor and ensure compliance with quotas, the fishing company was required to return all live fish to the holding cages at Farquhar prior to export. Now having a much larger area to cover than the land-based operation at Farquhar, permission to use a single mothership with 17 fishing dories was granted to the company. Later in the year, when fishing at Cosmoledo, the company was authorised to use another mothership for the sole purpose of transporting catches from the fishing grounds to the holding cages at Farquhar. Transshipment to any another vessel at sea was not allowed. Both the motherships and all the fishing dories were licensed by the local authorities and were required to display registration numbers. The vessels were not permitted to possess, store, transport or use any explosives or noxious substances, including sodium cyanide, nor were they permitted to use compressed air equipment for diving. The only fishing gear permitted was hook-and-line, as in the previous year (Bentley and Aumeeruddy 1999).

Figure 2. A fisher unloading a Napoleon wrasse (*Cheilinus undulatus*) in a holding cage.
© Riaz Aumeeruddy

The fishing company chartered a live reef fish transport vessel (LRFTV) from Hong Kong to export fish from Farquhar Atoll. The LRFTV obtained port clearance from authorities on Mahé Island before proceeding to Farquhar, where it was met by SFA offi-

2. SFA is a parastatal in the executive arm of the Seychelles Government, involved in fisheries research, management, development and training.
3. IDC is a public company mandated to manage and develop activities at several outer islands groups, including Farquhar, Cosmoledo, Astove, Assumption and Providence. It has some fishing activities at some of the outer islands, including Farquhar, where fish are salted and then exported to Mahé.

Figure 3. Fishers preparing the cages to transfer fish to the LRFTV. © Riaz Aumeeruddy

cers to supervise the loading (Fig. 3). On a typical trip, the LRFTV would load about 20 t before returning to Mahé Island to obtain clearance to leave territorial waters. In total, there were six export trips during the two-year project.

Monitoring the fishery

At Farquhar, fishing operations during 1998 were monitored by an SFA officer based on the atoll. The officer was tasked with recording species composition of the retained catch, estimating catch and (holding cage) mortality rates, as well as ensuring that fishing activities were in line with agreed procedures and conditions of license. In practice, collecting weight and other data from catches proved difficult, as fishers were keen to minimize handling of fish, so at this stage, catch weights were only estimated. Monitoring of fishing operations during the second year of the trial, in 1999, proved even more problematic, as it was not possible for SFA to station an observer on the mothership. Radio reporting of mothership position and catch and effort, as required under the license conditions, was subject to concerns over reliability of the data, and communication was further hampered by the language barrier. Since export quotas were the primary management control for the fishery and were also the basis for calculating management fees imposed on the fishing company[4], emphasis was placed on collecting accurate data while loading the LRFTV (Fig. 4), and additional SFA staff were flown to Farquhar to oversee this process. Consequently, the export data obtained were reliable and accurate.

Figure 4. Weighing the fish on the LRFTV. © Riaz Aumeeruddy

Target species, exports and cage mortality

Over the two-year trial, 102.3 t of fish were exported to Hong Kong (Table 1). Groupers in the genus *Epinephelus* constituted the majority of the exports, followed by coralgroupers or coral trout (*Plectropomus* spp.) and Napoleon wrasse (*Cheilinus undulatus*). The following species were exported in descending order of export quantities: *Epinephelus polyphekadion*, *Plectropomus punctatus*, *Cheilinus undulatus*, *E. fuscoguttatus*, *E. malabaricus*, *E. multinotatus* and *P. laevis*. After the last export of fish in January 2000, 15–20 t of fish remained in the holding cages. Although the fishing company had planned to send another LRFTV in late January 2000 to collect the remaining fish, a dispute between the company and its partners in Hong Kong delayed matters. In February 2000 the fishing company was requested by SFA to try to sell the fish locally, as the rate of mortality was increasing in the cages. With no local wholesalers or buyers showing interest, however, the company relinquished the fish to SFA and they were eventually released in the inner lagoon of Farquhar.

Accurate estimates of cage mortality rates were obtained only during the first year of the trial, when an SFA officer was stationed full time at the atoll. Mortality rates were high during the first fishing period (February–May) at Farquhar

4. A management fee of 0.60 US dollars (USD) kg^{-1} of fish exported was introduced in the initial license conditions to cover expenses incurred by SFA for monitoring and management. The fee was increased to USD 1.00 kg^{-1} in the second year to cover the additional expenses of monitoring the remote mothership operations.

Table 1. Exports of LRFF (kg) by fishing location, fishing period and the three main species groups.

Fishing location	Fishing period	*Plectropomus* spp.	*Epinephelus* spp.	*Cheilinus undulatus*	Total
Farquhar	Feb-May 1998	4 920	10 558	5 556	21 034
Farquhar	May-Aug 1998	5 085	5 837	1 061	11 983
Providence	Jan-Mar 1999	2 899	6 934	4 131	13 964
Providence	Mar-Jun 1999	5 051	5 821	3 697	14 569
Cosmoledo	Oct-Nov 1999	4 032	10 180	1 508	15 720
Cosmoledo	Nov-Dec 1999	639	20 846	3 519	25 004
Total:		**22 626**	**60 176**	**19 472**	**102 274**

(Table 2), representing 6389 kg of fish, or about 23.3% of the quantity caught (excluding the fish used as bait and feed). Part of the problem resulted from high densities, as the original 12 cages were insufficient given the (low) frequency of export; 12 additional cages were constructed at the end of March 1998. The feeding regime was initially poorly maintained. Once these two problems were rectified, the mortality rate improved, falling to 16.3% of the quantity caught in the second fishing period (May–August). Mortality rates (in the first fishing period) differed among species, with the epinephelids and plectropomids showing much higher rates (24.2% and 35.1%, respectively) than Napoleon wrasse (6.2%), probably due to the fact that densities in the serranid cages were greater. Operations at Farquhar slowed down from the beginning of July due to poor weather conditions at the atoll (rough seas associated with southeasterly trade winds). For the remainder of 1998, fishing was conducted only to provide feed; lower quantities of fish were consequently captured and exported during the second period of the year (Table 2). Also shown in Table 2 are estimates of the amount of bait and feed (obtained from both targeted fishing and bycatch of LRFF fishing) used in the operation, as well as estimates of total catches of all fish (the sum of exports, cage mortalities, bait and feed).

Table 2. Total catches at Farquhar in 1998, by fishing period, as determined from exports, mortalities and (approximate) bait and feed estimates.

Fishing period	Exports (kg)	Cage mortality (kg)	Bait and feed (kg)	Total catch estimate (kg)
Feb-May	21 034	6 389	10 000	37 423
May-Aug	11 983	2 331	5 000	19 314
Total	**33 017**	**8 720**	**15 000**	**56 737**

Implications for management

At the end of the trial in 1999, the fishing license was not renewed pending a review of the fishery. Four key areas of concern were identified regarding the long-term viability of a LRFF fishery of this type, all of which have been expressed in other regions in which such fisheries have operated (Sadovy et al. 2003).

Sustainability

The sustainability of the LRFF fishery was the major concern. The shore-based operation at Farquhar enabled high levels of fishing effort to be applied over a small fishing ground. As the operation obtained high catch rates for the target species, the amounts retained for export after the first fishing season (Table 1) rapidly reached a level equal to what had been estimated as maximum sustainable yield (MSY), 31.9 t, for all species available to a hook-and-line fishery in the shallow (0–75 m) stratum (Mees et al. 1998). Although total exports of LRFF caught at Farquhar (33 t) were roughly equivalent to this MSY estimate, when mortality, bycatch and targeted fishing for feed were taken into consideration, the total catch from Farquhar exceeded MSY by about 25 t. Overexploitation was achieved within 60 days of fishing by 8–14 fishers operating daily, and the exploitation rate was lessened only by rough weather during the second fishing period of 1998.

Aspects of their demography and reproductive biology (Shapiro 1987; Sadovy 2001) render the target species vulnerable to intensive fishing. Many juvenile fish, particularly Napoleon wrasse, were taken, and although the fishers did not target particular fish sizes, the market's preference for plate-sized fish may have led to such size selectivity over time, with severe implications for fishery sustainability. Of particular concern was the targeting of

spawning aggregations (Domeier and Colin 1997). Little was known regarding the status of grouper spawning aggregations at the time of the LRFF trial. The IDC, which manages many of the outer islands, knew that large aggregations of *E. polyphekadion* and *E. fuscoguttatus* formed at Farquhar in December and January (Robinson et al. in prep.), information that was used to justify the LRFF fishery commencing in February so as to avoid aggregation targeting. At Cosmoledo, however, which has no permanent IDC presence, aggregations may have been targeted in the November–December 1999 fishing period. Research conducted since the trials has identified aggregations of *E. polyphekadion* and *E. fuscoguttatus* at the atoll, and histological evidence indicates that February is the last month of the spawning season (SFA unpublished data). Based on what is known regarding the duration of spawning seasons in these species (Domeier and Colin 1997; Rhodes and Sadovy 2002; Pet et al. 2005), it is likely that aggregations also form in December and possibly November. Assuming fishing effort and mortality rates did not differ significantly between the two fishing periods at Cosmoledo, the 100% increase in export quantities of epinephelids between the two periods (Table 1) may be indicative of aggregation fishing.

Conflict with local fishers

In Seychelles, the law reserves all demersal resources to local companies or individuals. Traditional artisanal fishers perceived the LRFF fishery as being foreign-owned and of little economic value to the country. Although the fishing company was locally registered and had Seychellois owners, the principal shareholder of the company was Chinese and had only recently nationalized. Furthermore, all fishers and crews employed by the company were recruited from China. Traditional fishers also resented the wastage of non-target species. Most of the bycatch, mainly comprising emperors (Lethrinidae), snappers (Lutjanidae) and lower value groupers (Serranidae), was used for feed and bait. Since all of these species are targets for traditional fisheries and are relatively valuable in local markets, artisanal fishers considered the LRFF fishery to be not only unsustainable but an infringement of their rights.

Biodiversity

Napoleon wrasse is the most valued target species, as it fetches the highest price on Asian markets, especially plate-sized fish that can reach more than USD 100 kg^{-1} in restaurants. In Seychelles, there is little demand for this species by the local population and it is not targeted by traditional fishers. Given that this species was listed on the IUCN Red List of threatened species, fisheries managers were concerned that the LRFF fishery could place this species at risk in Seychelles. Moreover, there was mounting pressure internationally to list this species on Appendix II of the Convention on International Trade in Endangered Species of Wild Flora and Fauna (CITES). If CITES listing was attained, any country wishing to export Napoleon wrasse to a country that was party to CITES would need to certify that the fish being exported was legally obtained and that the export would not be detrimental to the survival of the species. Seychelles did not want to be seen as opening a fishery that was targeting a listed species.

Economic viability

SFA considered that the organisation of the LRFF operation, based largely on Chinese manpower and trading links, was not an economically viable fishery for the country. The local LRFF fishing company was responsible for the logistics of the project, paid the salaries of three people based on Farquhar to look after the holding cages, and paid for local expenses (fuel, local supplies, shipping agent fees, port dues, local fishing licenses and management fees). The buyer in Hong Kong paid for the salaries for the crew and fishermen and supplied the mothership, fishing dories, fishing gear and the funds for the charter of the LRFTV. For its services, the local LRFF fishing company reported being paid USD 3 kg^{-1} of fish FOB Farquhar, irrespective of the size and species of the fish. At that rate, the total exports of live fish for the two-year trial were valued at USD 306,822. The price obtained for LRFF at Farquhar was no higher than the price for fresh or processed fish on the local retail market. Seychellois wholesalers and processors on Mahé pay fishers an average price of USD 2.70 kg^{-1} for groupers, a price that has remained stable since 1998. Moreover, when fish are sold on local retail markets and to restaurants and hotels, there is substantially more revenue generated for the local economy.

LRFF prices paid to fishers and prices on the retail market in Hong Kong can be considerably different, as there are usually several intermediaries, each of which adds mark-up on the price (Sadovy et al. 2003). The export price of USD 3 kg^{-1} reportedly paid to the company in Seychelles is low compared to beach prices in other countries. In 1999, the average beach price for the Napoleon wrasse was USD 8–10 kg^{-1} (nominal) in Indonesia and USD 9–10 kg^{-1} in Australia, whilst for brown-marbled grouper average beach price was USD 5–6 kg^{-1} (nominal) in Australia (Sadovy et al. 2003). Prices offered in Seychelles are expected to be lower than

in countries closer to Hong Kong, because of higher transportation costs and mortality rates during transport.

In terms of employment, no local jobs were created by this fishery. Even if given the opportunity, local fishers would have been reluctant to work on board the mothership because of communication problems and poor living conditions. The development of a small-scale LRFF fishery that involved local fishers and crew may have been more beneficial for the country. In February 1998, SFA organised a study mission to Hong Kong to research the LRFF trade and to examine ways to attract better prices. However, there were problems establishing reliable contacts with various middlemen and the difficulties of trading further up the supply chain were manifest. Even if more direct links to middlemen could be established for a small-scale, more locally operated fishery, the constraints of transportation would probably have been insurmountable without direct air links between Seychelles and the market, and without taking advantage of the latest technological advances in reducing mortality rates.

Closure of the LRFF fishery

Following the cessation of the LRFF fishery trial in 1999, SFA received three substantive proposals from Seychellois businessmen for the development of a locally operated LRFF fishery. Based on findings from the trial and increasing reports of problems associated with the fishery in other regions (Smith 1997; Mapstone et al. 2001), SFA adopted a precautionary approach and maintained its policy of discouraging such ventures. In the meantime, two other developments strengthened the case for prohibiting the LRFF fishery altogether:

Concerns over the status of reef fish spawning aggregations, which were known to be targeted by traditional artisanal fishers (Robinson et al. 2004), and may have been targeted in the LRFF fishery trial, led SFA to implement a four-year research and management programme for reef fish spawning aggregations (2002–2005). The idea of protecting grouper spawning aggregations has received widespread support from local fishers and the designation of closed areas and seasons is at an advanced stage. It was recognised by the fisheries managers that protection of aggregations and development of a LRFF fishery were incompatible aims for the management of groupers and other species.

Many demersal finfish resources on the Mahé Plateau, a large shallow plateau surrounding the populated granitic islands, are overexploited while those in the outer islands are lightly exploited (MRAG 1996; Mees et al. 1998). To reduce pressure on inshore stocks (i.e. primarily demersal fish and semi-pelagic fish such as trevallies), and to realise the fisheries potential on the outer islands, plans for the development of outer island fisheries-related infrastructure in support of demersal hook-and-line fisheries have been proposed. Because of the high potential for ecotourism on the outer islands, which is already developing, the protection of spawning aggregations and restrictions on unsustainable fisheries were viewed as fundamental precautionary measures.

The Fisheries Act (1984) is the principal piece of legislation governing fisheries in Seychelles. Gazetted in June 2005, the live fish trade regulations (Fisheries (Amendment) Regulations 2005: S.I. 32 of 2005) prohibit the fishing of all finfish (all cartilaginous and bony fishes) for the live fish trade, including both the food and aquarium trades. Fishing of other species for the live fish trade, including crustaceans (e.g. the spanner crab, *Ranina ranina*), is subject to authorisation and to the imposition of conditions on fishing licences and export permits. These regulations apply to wild-caught live fish; live finfish from mariculture projects can be exported with an appropriate permit.

Discussion

Prior to the trials, the authorities in Seychelles were largely unaware of LRFF fisheries and trade. Valuable lessons have been learned. Because only certain species and size classes of fish are acceptable for the live fish markets, biomass and sustainable yield estimates that are available for reef fish as a group were found to be inappropriate as a basis for managing the LRFF fishery (Mees et al. 1998). Because of high rates of mortality and bycatch, limits should be set on total catch rather than on exports. Strict monitoring and a rapid management response are necessary for the LRFF fishery, especially where vulnerable species are targeted; these requirements were not achieved in this trial. From the outset, it was clear that monitoring and ensuring compliance would be demanding and expensive to implement in remote locations of the EEZ. Although controls on unsustainable fishing practices (e.g. cyanide fishing) appeared successful, a lack of knowledge on spawning aggregations at the time may have exposed several aggregation sites to excessive fishing. Timely recognition of these management deficiencies and other factors contributing to the closure of this fishery probably prevented extreme stock depletions at Farquhar, which in 2002 still maintained some of the highest abundances of large serranids and Napoleon wrasse in the Indo-Pacific (J.H. Choat, James Cook University, pers. comm. 2002).

The export prices reportedly paid by buyers in Hong Kong to the local LRFF company were low considering the costs incurred by the company. Moreover, it was difficult to see how a more sustainable, small-scale, locally operated LRFF fishery could achieve greater benefits than attainable through existing local markets, even if beach prices for LRFF could be improved. While a (presumably) economically viable, small-scale LRFF fishery has been established in Maldives, the situation there is different in that there is less demand for the target LRFF species on local markets, as tuna is the preference of the local population (Shakeel and Ahmed 1997), and there is consequently less competition with traditional fishers.

As stocks of LRFF target species are depleted at ever increasing distances from the main markets, continued demand and improvements in air transport technology and general trade links may erode barriers to expansion of the trade (Sadovy et al. 2003). Countries of the WIO, already some of the least developed in the Indo-Pacific, will need to make informed decisions about whether to support the development of LRFF fisheries, taking into account the costs and benefits of the LRFF trade. Initiatives to sensitize and educate fishers and fisheries managers of the many issues surrounding this trade are lacking in the region, and may be required should an expansion occur in a westward direction.

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Leopard coralgrouper (*Plectropomus leopardus*) management in the Great Barrier Reef Marine Park, Australia

Martin Russell[1]

The Great Barrier Reef Marine Park (GBRMP) is a multiple use marine protected area managed by the Great Barrier Reef Marine Park Authority (GBRMPA), a Commonwealth Statutory Authority. The GBRMP spans 345,400 km^2 adjacent to the Queensland east coast, is 2300 km long, and contains 2900 reefs.

Leopard coralgrouper (*Plectropomus leopardu*s) are targeted by the Queensland Coral Reef Fin Fish (CRFF) fishery, which uses hook-and-line and speargun (recreational) throughout the GBRMP. The CRFF fishery is managed by the Queensland Department of Primary Industries and Fisheries. Most of the leopard coralgrouper taken in this fishery is exported for the Asian live food fish trade.

Many coral reef fish may form spawning aggregations on the Great Barrier Reef (GBR) (Russell 2001). A key target species in the CRFF fishery that is known to form spawning aggregations on the GBR is the leopard coralgrouper. Leopard coralgrouper are known to move to and from spawning aggregations on the reefs they inhabit, rather than moving large distances between reefs (Davies 2000). More information is needed on the movement of leopard coralgrouper to spawning aggregations, including the distances they travel and the possibility of their using corridors between interconnected reefs. Despite a lack of specific information, the best available information is used for management. New measures have been adopted recently. In 2004, the Queensland Fisheries (Coral Reef Fin Fish) Management Plan 2003 introduced a package of fisheries management tools, including a commercial total allowable catch (TAC), revised size limits, revised recreational bag limits, and spawning season closures.

A commercial TAC of 1350 t is applied to coral trouts generally (*Plectropomus* spp.) and is currently set at the level of catch taken by the commercial fishing sector in 1996, which is thought to represent full exploitation of the fish stocks across the GBR.

The recreational bag limit is applied to coral trouts generally and is currently set at seven fish in possession per person. The biologically precautionary minimum legal size limit on the take of leopard coralgrouper by commercial and recreational fishers is 38 cm in total length. The size limit is based on information about size at maturity, which is about 32 cm, and size at sex change from female to male, which occurs at about 42 cm (Mapstone et al. 2004). Even though the size limit is set to ensure that most fish spawn at least once before recruiting to the fishery, this does not prevent the take of larger, older male fish. The excessive take of such fish could cause skewed sex ratios, sex change at a smaller size, and sperm limitation in the stock.

To protect the main spawning time for most CRFF fishery species, three nine-day spawning season closures occur over the new moons in October, November and December each year. These closures cover all CRFF fishery species, and possession of any CRFF fishery species is prohibited during these times. Placing a seasonal closure on only one CRFF fishery species or species group may not adequately protect those species, and is also difficult to enforce. The seasonal spawning closures are based on the peak spawning time for leopard coralgrouper, being the new moon phases of the spring and summer months on the GBR. Leopard coralgrouper was chosen as an indicator species because this is the key target species in the CRFF fishery, and more information was available for this species than for other species targeted by the fishery. Studies of the spawning behaviour of leopard coralgrouper on the GBR indicate that for several days on either side of the spring new moons they aggregate to spawn (at dusk) (Samoilys and Squire 1994; Samoilys 1997; Zeller 1997).

There is some anecdotal information on reef fish spawning aggregations from fishers with a historical background in the CRFF fishery. Some fishers speak of large catches of certain species at particular locations and times in the past. However, this is not overly apparent in the commercial fishing log-

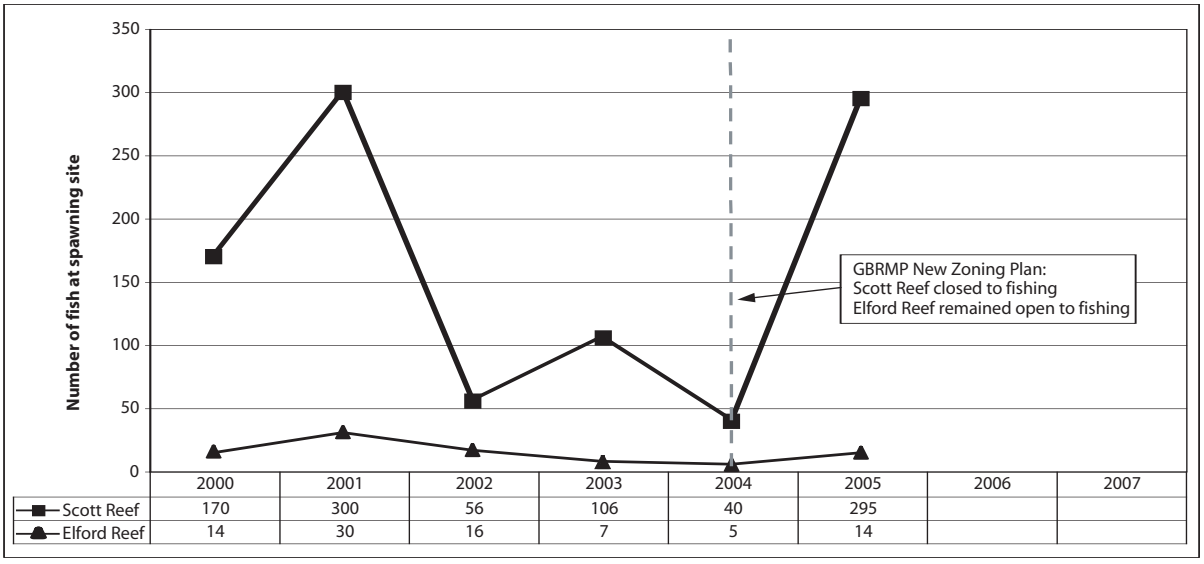
1. Great Barrier Reef Marine Park Authority, PO Box 1379, Townsville, Queensland, Australia 4810; and Society for the Conservation of Reef Fish Aggregations, 901-B Pier View Way, Oceanside, CA 92054, USA. Email: m.russell@gbrmpa.gov.au

book records. This could be due to inaccurate logbook reporting of catch and effort, that logbook reporting is not specific to particular reefs, and species misidentification. It is likely that some fishers actively fish spawning aggregations on the GBR, whilst others are not aware of the locations and may accidentally fish them at times.

Because the CRFF fishery operates in a World Heritage marine protected area, a higher level of conservation-based legislative requirements are in place under the Great Barrier Reef Marine Park Act 1975. The Australian government recently introduced an unprecedented conservation initiative to better protect the GBRMP. The GBRMP was re-zoned in July 2004, resulting in an increase in the size of no-fishing areas from 4.5% to 33% of the total park size. The re-zoning was designed to protect representative examples of the biodiversity of the GBRMP; closures cover all habitat types described in 70 different bioregions. The amount of reefal area (reef and shoal habitat), the area predominantly used by the CRFF fishery to target leopard coralgrouper, now closed to fishing is about 30%.

The GBRMPA is aware of several hundred possible fish spawning aggregation sites throughout the GBRMP. However, most of these sites are known only from anecdotal information, and only a few of these sites have been validated using in-water visual surveys or catch sampling. The validated sites were considered in the re-zoning of the GBRMP, and the anecdotal sites were considered only for supporting ecosystem information. Considering it is likely that leopard coralgrouper form aggregations on most reefs on the GBR, the 30% protection of all reefal habitats gives confidence that many spawning aggregation sites for this species are afforded some protection from fishing. However, this is not the case for other CRFF fishery species that may move large distances to spawning aggregations sites yet to be identified, and therefore some of these sites may not be protected from fishing.

Two key spawning aggregation sites for leopard coralgrouper, at Scott Reef and Elford Reef, offshore from Cairns, have been monitored during the key spawning months of September, October and November each year for the past 15 years (Samoilys et al. unpublished). The October new moon is the peak time leopard coralgrouper have visited the aggregation sites. These two sites have been fished at varying levels over this time. Under the new zoning of the GBRMP, Scott Reef has been zoned as a Marine National Park (green zone), which prohibits fishing, and Elford Reef has been zoned as a Conservation Park (yellow zone), which allows limited line fishing. This has created a very valuable and unique research and monitoring opportunity to examine the impacts of the rezoning, such as documenting over time the changes in numbers of leopard coralgrouper visiting the aggregation sites during the October new moon on these two reefs. Preliminary site assessments one year after the re-zoning of Scott Reef as a green zone have shown that the numbers of leopard coralgrouper visiting the spawning aggregation site have increased. In contrast, the numbers of leopard coralgrouper visiting the Elford Reef spawning aggregation site have remained relatively constant (Fig. 1). However, it is too soon after the re-zoning to conclusively determine if the re-



	2000	2001	2002	2003	2004	2005	2006	2007
Scott Reef	170	300	56	106	40	295		
Elford Reef	14	30	16	7	5	14		

Figure 1. Leopard coralgrouper numbers at Scott Reef and Elford Reef spawning aggregation sites during October new moon, 2000 to 2005.

zoning has affected the number of fish visiting these spawning aggregation sites. These sites will be monitored over time to help determine this.

The management measures on the GBR are exceptional in that a precautionary approach has been taken, to a certain extent, to ensure the long-term sustainability of the reef fish resources. This is preferable to the many situations around the world in which management measures, such as spawning season closures, were introduced only after it was found that spawning aggregations were in decline.

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Live reef food fish trade causes rapid declines in abundance of squaretail coralgrouper (*Plectropomus areolatus*) at a spawning aggregation site in Manus, Papua New Guinea

Richard J. Hamilton[1] and Manuai Matawai[2]

Background

Overfishing by the live reef food fish trade (LRFFT) is recognised as being one of the greatest threats to fish spawning aggregations (FSA) of coral reef fish (Johannes and Riepen 1995; Sadovy and Vincent 2002; Sadovy et al. 2003; Warren-Rhodes et al. 2003). However, direct evidence of FSA loss or decline as a result of LRFFT activities is negligible in the Indo-Pacific (Rhodes and Warren-Rhodes 2005), with the majority of documented accounts being based on the local knowledge of fishers (Johannes et al. 1999; Hamilton et al. 2005a; Sadovy 2005; Sadovy and Domeier 2005). In this paper we present evidence from Melanesia that quantitatively demonstrates the impact of the LRFFT on the FSA of the squaretail coralgrouper (*Plectropomus areolatus*). We do this by compiling underwater visual census (UVC) data that were collected from three grouper FSA sites located on the south coast of Manus, in Papua New Guinea. Two of the three monitored sites (Sites 29 and 33)[3] have never been opened to the LRFFT, while the third site (Site 35) was exploited to supply the LRFFT between July and December 2005. Our preliminary results show that relative to the two unfished "control" sites, *Plectropomus areolatus* abundances and densities at Site 35 declined very rapidly following the commencement of the LRFFT. The UVC survey results also show that peak FSA of *P. areolatus* formed at Sites 29 and 33 between March and June 2006, as was predicted by local fishers. During the same period, no clearly defined peak season was detected at Site 35.

Environmental and social setting

The locations, biological parameters, and status of more then 10 grouper FSA sites in Manus (Fig. 1) were documented in several local knowledge and UVC surveys that were commissioned by the Papua New Guinea National Fisheries Authority (NFA), The Nature Conservancy (TNC) and the Society for the Conservation of Reef Fish Aggregations (SCRFA) (Squire 2001; Hamilton 2003; Hamil-

Figure 1. Manus Island and the Hermit Islands, Papua New Guinea.

1. The Nature Conservancy, Indo-Pacific Resource Centre, PO Box 8106, Woolloongabba, Qld 4102, Australia. Tel: +617 3214 6913. Fax: +617 3214 6999. Email: rhamilton@tnc.org
2. The Nature Conservancy, Manus Field Office, PO Box 408, Lorengau, Manus Province, Papua New Guinea. Tel: +675 470 9368. Email: manuai.tnc@global.net.pg
3. By convention, The Nature Conservancy refers to aggregations by site numbers rather than their location names so as to limit dissemination of aggregation location information

ton et al. 2004). Out of all of the known FSA sites, three sites, Sites 29, 33 and 35, were identified as being of very high conservation priority. These three FSA sites are all located on reef promontories along the south coast of Manus Island and come under the customary ownership of four communities from the Titan tribe. They are the largest of all known grouper FSA sites in Manus and they all have a high biodiversity value (Hamilton et al. 2005b). The squaretail coralgrouper[4], brown-marbled grouper (*Epinephelus fuscoguttatus*) and camouflage grouper (*E. polyphekadion*) are known to aggregate at these sites at overlapping times and locations. Local fishers report that *P. areolatus* FSA form at Sites 29, 33 and 35 during the third quarter of every lunar month of the year, with a peak season in the months of March, April and May, during which time the abundance of *P. areolatus* at FSA sites is an order of magnitude higher than in other months of the year.

In early 2004 we held community awareness meetings on the importance of conserving grouper FSA with the four Titan communities that own the reefs on which Sites 29, 33 and 35 are located. All of the communities subsequently expressed an interest in managing their FSA sites and requested that TNC provide them with technical assistance in their efforts. Over a period of several months the communities discussed the issues among themselves and asked us for advice on a variety of management options they were considering for their spawning sites. By May 2004 all four Titan communities had banned spearfishing at these three FSA sites in the 10 days leading up to and including the new moon in every month of the year. Capturing fish for sale was also banned. Subsistence hook-and-line fishing was allowed at these sites but fishers could only catch enough fish to meet their daily food requirements. The Titan communities all made a point of not stating how long their harvesting restrictions would be in place. Rather, the communities stated that the suitability and effectiveness of these initial restrictions would be reassessed in several years' time.

Although compliance with these rules was strong, the robustness of community-based management to outside commercial pressures were tested in June 2005 when NFA and the Manus Provincial Government allowed the New Guinea Islands Sea Products (NGISP) LRFFT company into the south coast of Manus[5]. NGISP immediately expressed interest in fishing Sites 29, 33 and 35, along with several other known grouper FSA sites in the area. While the traditional owners of Sites 29 and 33 did not allow the company access to their reefs (the fishing was actually done by local fishers, who sold the catch to NGISP), the owners of Site 35 did. Between July and December 2005 the community that owns the reef on which Site 35 is located caught 13 tonnes (t) of fish for the LRFFT. Approximately 50% of this catch was made up of *P. areolatus*, with the humphead wrasse (*Cheilinus undulatus*) and *E. fuscoguttatus* being the second and third largest components of the catch. At least half of the *P. areolatus* captured was taken from Site 35 (personal observations of the author, Manuai Matawai, July to December 2005).

While many *P. areolatus* were captured by fishers drop-lining from canoes, some fishers utilized a unique and highly efficient means of capturing *P. areolatus*. A fisher would snorkel on the surface at Site 35 with a small handline, and when a *P. areolatus* was sighted on the reef below he would lower a baited hook directly in front of the fish. Hooked fish would be hauled up by the snorkeler and placed in a nearby canoe. Fishers report that this method has a much higher catch per unit of effort (CPUE) rate than handline fishing from a canoe.

UVC methods

The first UVC surveys to be conducted at Sites 29, 33 and 35 were undertaken in the week leading up to the new moon in March 2001 (Squire 2001). Squire's UVC methodology involved descending to a depth of 20–30 m on scuba and swimming along the entire length of the aggregation site with the prevailing current, recording on underwater paper the total number of *P. areolatus*, *E. fuscoguttatus* and *E. polyphekadion* seen. Fish characteristics that are indicative of spawning in these species were also documented, such as colour change, territoriality, and gravid females. Manuai Matawai showed Squire the locations of Site 29, 33 and 35 and participated in Squire's 2001 surveys. In May and June 2004 he resurveyed the three sites using identical methods to those described above.

4. In this paper we limit our discussion to the effect of the LRFFT on *P. areolatus* aggregations. This species is the most abundant grouper at all three sites.
5. A second LRFFT company, Golden Bowl PNG Ltd, began operating around the Ninigo and Hermit Islands, within Manus Province to the west of Manus Island, in June 2005. This is the same area that was fished by LRFFT operations from 1990–1992. Those operations were stopped by the provincial government in 1992 because of various social and environmental concerns (Richards 1993; Gisawa and Lokani 2001). The 2005 Golden Bowl PNG Ltd operation purchased approximately 4 t of groupers and humphead wrasse (*Cheilinus undulatus*) from the Ninigo and Hermit Islands over a period of approximately one month. After the first month of operation a physical confrontation occurred between resource owners and company representatives, apparently because the company fished within two no-take *tambu* areas that the community had set aside as conservation areas. The company representatives subsequently left the region, and by September 2005 Golden Bowl PNG Ltd had left Manus Province (Hamilton et al. 2005b).

Manuai Matawai's 2004 surveys confirmed the presence of large FSA of both *P. areolatus* and *E. fuscoguttatus* at all three sites. At all sites *P. areolatus* and *E. fuscoguttatus* overlap in their spatial distributions, although *P. areolatus* primarily aggregates in the shallower part of these sites (3–15 m depth), whereas *E. fuscoguttatus* is primarily found in the deeper part (15–40 m depth). The UVC surveys conducted at Sites 29, 33 and 35 in May and June 2004 revealed that the number of groupers and the areas over which they aggregated were too large to enable total counts to be made in a single scuba dive, so a decision was made that in future surveys, fish would be counted over just a portion of the area in which they aggregate (Hamilton et al. 2004).

In July 2004, after consultations with the relevant communities, permanent belt transects were established at Sites 29, 33 and 35 (Fig. 2). Two transects were established at each site: a deep transect with a midline at 25 m that samples the high density *E. fuscoguttatus* and low density *P. areolatus* aggregations and a shallow transect with a midline at 10 m that samples the high density *P. areolatus* and low density *E. fuscoguttatus* aggregations. The permanent belt transects are all 100 m long and 10 m wide. Transects were established using the methodology set out in the TNC FSA monitoring manual (Pet et al. 2006). Logistical difficulties prevented monthly monitoring in much of 2004 and the first half of 2005.

Routine monthly monitoring commenced at Sites 29, 33 and 35 in July 2005 and has continued to the present. Monitoring occurs in the three days leading up to the new moon of each month, and involves two scuba divers counting all of the *P. areolatus*, *E. fuscoguttatus* and *E. polyphekadion* sighted within the transect boundaries. Each transect is surveyed once per month. For the purpose of this paper, only the monthly *P. areolatus* data collected along the single shallow 1000 m² transects at each site are presented. With the exception of the Squire (2001) data, all counts of *P. areolatus* presented in this paper were made by Manuai Matawai.

UVC results

Titan fishers report that the largest *P. areolatus* FSA form at Site 35 (Hamilton 2003; Hamilton et al. 2004). This assertion is supported by UVC surveys that were conducted in March 2001 and May and June 2004 (Fig. 3). In all years and months sur-

Figure 2. Manuai Matawai (left) and Jerry Pakop (right) conducting monitoring along permanent transects at Site 33. Photo credit and copyright, Eric Henningsen, Ion Digital Films.

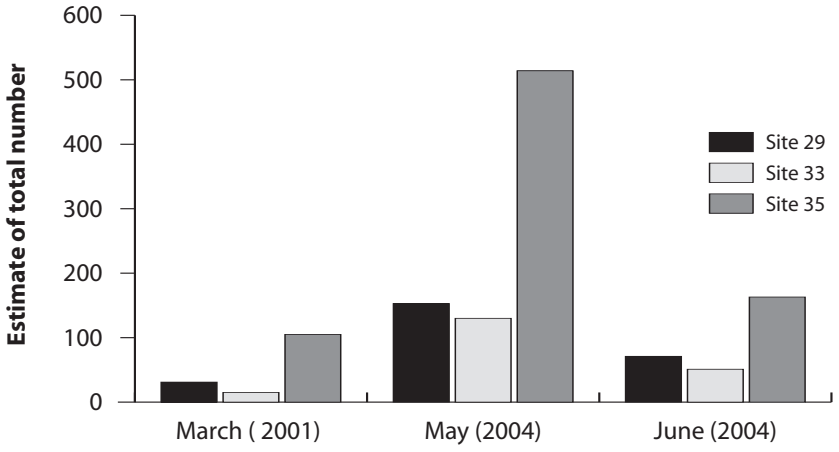

Figure 3. Number of *P. areolatus* counted at each site on a single dive prior to the new moon (these counts were intended to approximate the total number of fish at each site). March 2001 data were collected by Squire (2001). May and June 2004 data were collected by Manuai Matawai (Hamilton et al. 2004).

veyed, *P. areolatus* were at least twice as abundant at Site 35 as at Sites 29 and 33. Note that these counts of *P. areolatus* significantly underestimated total abundance during months when large aggregations formed. The 2001 and 2004 surveys focused predominantly in deeper water in order to get accurate counts of *E. fuscoguttatus*, but *P. areolatus* aggregate right up onto the reef flats in 2–3 m of water. We estimate that in May 2004, the actual total numbers of *P. areolatus* at the three surveyed sites were at least double the numbers counted (Hamilton et al. 2004).

Regular new moon monitoring along permanent belt transects began in July 2005. Figure 4 shows the densities of *P. areolatus* along 1000 m² shallow-water transects at each aggregation site between July 2005 and September 2006[6]. The UVC data show that densities of *P. areolatus* at Site 35 were, contrary to the observations in 2001 and 2003–2005, lower than at the two unfished sites in 2006, and in 2006 no peak season was detected at Site 35.

Discussion

As was predicted by local fishers, UVC surveys show that *P. areolatus* were present at the FSA sites in virtually every month of the year between July 2005 and September 2006, with a marked peak season at Site 29 and 33 between the months of March and June 2006. The UVC surveys also show that during the peak season in 2006 much higher abundances of *P. areolatus* were seen at the two unfished sites than at the commercially fished site. This finding contrasts dramatically with local knowledge and historical UVC data that show that prior to 2006, the largest *P. areolatus* aggregations formed at Site 35 (Squire 2001; Hamilton 2003; Hamilton et al. 2004). Indeed, during the peak season in 2006 *P. areolatus* abundances at Site 35 fell well short of abundances seen at this site during the tail end of the 2005 season. The absence of a detectable peak season at Site 35 in 2006 may also be indicative of overfishing by the LRFFT.

However, our data series to date is limited and we will require several more years of continuous monitoring before the impact of the LRFFT at Site 35 can be assessed with confidence. At this stage our limited available data do not allow us to rule out the possibility that the annual variation in the numbers of *P. areolatus* sighted at Site 35 represents natural variation in response to factors such

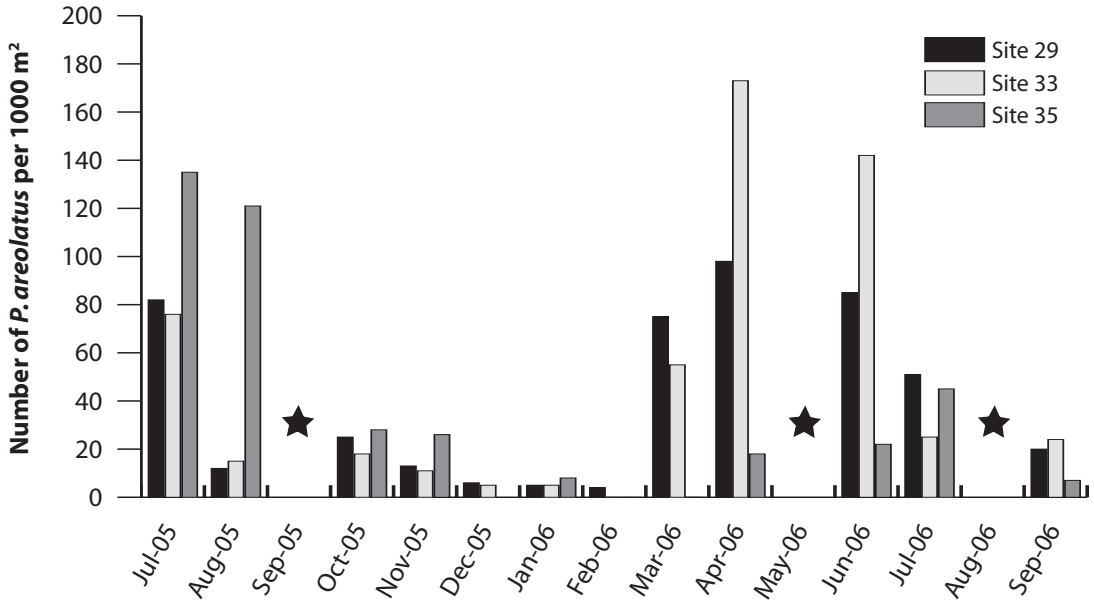

Figure 4. Number of *P. areolatus* counted in each shallow water 1000 m² transect at Sites 29, 33 and 35 (these counts are not directly comparable with those in 2001 and 2004). The symbol ★ indicates that no UVC surveys were conducted in that month. Between July and December 2005, Site 35 was fished to supply a LRFFT operation.

6 . The shallow water transects at Site 29 and 35 cover approximately 15 and 12 per cent, respectively, of the shallow water *P. areolatus* aggregation areas (Hamilton et al. 2005b). Estimates of total abundance of *P. areolatus* at depths of 3–15 m at Sites 29 and 35 in any particular month can be made by multiplying transect counts by 6.72 and 8.13, respectively.

as varying levels recruitment. Indeed, a longer term monitoring programme that focused on three FSA sites in Palau revealed considerable variation in the size of *P. areolatus* FSA between consecutive years, and such variability could not be attributed to fishing pressure (Johannes et al. 1999). These considerations aside, all available evidence indicates that in only six months of LRFFT activity the abundance of *P. areolatus* at Site 35 were reduced to one-third of what they were previously.

The Manus case study presented here provides some insights for conservationists and fisheries managers working in Papua New Guinea. It demonstrates that simply raising awareness of the potential environmental consequences of engaging in the LRFFT and targeting FSA will not necessarily prevent communities from entering into this trade. In southern Manus the same community that readily imposed and enforced some harvesting restrictions on Site 35 in early 2004 following TNC awareness campaigns also engaged in LRFFT operations at the very first opportunity. The about-turn of the community that owns Site 35 highlights the challenges of biodiversity-focused conservation and sustainable fisheries management in remote underdeveloped areas of Papua New Guinea. Within Melanesia, fundamental aspirational differences often exist between various sectors of a community with regards to resource exploitation levels and the management and conservation of FSA. The effective management and conservation of FSA will require approaches that acknowledge and deal positively with these aspirational differences.

The LRFFT operation around Site 35 in 2005 deeply divided the community that holds ownership of this site, with many individuals upset about the prices received and ecological damage caused by the trade. Yet despite this, in July 2006, Site 35 and surrounding reefs were again opened up to the LRFFT. Clearly, in spite of the social and ecological problems caused by the LRFFT, the lack of income-generating opportunities in the rural coastal areas of Manus means that interest in the LRFFT remains high.

On a more positive note, social and environmental concerns about the LRFFT resulted in the communities that own Sites 29 and 33 not participating in the LRFFT in 2005, and in 2006 the community that owns Site 29 took a further step towards conserving its grouper FSA by announcing a complete ban on all types of fishing at Site 29. This community is also working to have its community-based management regulations recognized and endorsed through local level government laws.

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History and status of commercial live fish fisheries in California and the United States West Coast

Scot Lucas[1]

The coastal waters of the state of California, on the west coast of the United States, support a diverse range of substrates and depths, including deep submarine canyons, offshore islands and an extended shallow water shelf. Below 34°N the coastline takes on a more east–west orientation, creating a recognized biogeographical break in the coastline at Point Conception (Fig. 1). It is at Point Conception that the colder California Current from the north and the warmer California Countercurrent from the south meet. Although there are some cosmopolitan bottom-associated species, such as some rockfish and cabezon, for the most part, the composition of commercially targeted fish species differs greatly north and south of Point Conception. The part of the state north of Point Conception is referred to here as "northern California", and the part to the south, "southern California".

Since its emergence in the late 1980s, California's live fish commercial fishery continues to make up a small but significant portion of the state's total commercial finfish catch. Live landed commercial fishing evolved from the demand for specialty foods in Asian restaurants and markets in southern California (McKee 1993). What started out as an alternative fishery quickly expanded into a multimillion dollar industry by the early 1990s (Table 1). Part of the reason for this boom was the willingness of consumers to pay a much higher price for live fish than dead fish of certain species, particularly plate-sized fish. That premium was passed on to fishermen in the form of higher ex-vessel prices (price per unit of weight paid to fishermen upon landing of catch) for live fish. Many establishments offered consumers the opportunity to pick out a fish of their choice from tanks right in the restaurant. In general, a mar-

Figure 1. The west coast of the United States and the northeast Pacific Ocean, showing Point Conception as the boundary between northern and southern California.

1. California Department of Fish and Game, Monterey, California 93940, USA. Email: slucas@dfg.ca.gov

ket developed for fish that live in shallow waters close to shore and did not necessarily require a large boat to capture. In many cases there was no need for fishermen to bring fish to market at all; the buyer would meet a fisherman right at the dock to transport catch directly to the restaurant or market in a live state. Among other evolving issues, it was the rapid expansion and mobile nature of the fishery and the small target size of certain species that began to concern fishery managers.

Table 1. Approximate landings, ex-vessel value, and average ex-vessel prices in California of the 10 most commonly landed commercial live fish categories, 1994–2005 (values and prices have been adjusted for inflation and are expressed in 2005 US dollars, USD).

Year	No. of fishermen with at least one live landing	Catch weight (t)	Ex-vessel value (USD)	Average price (USD/kg)
1994	822	738.0	4 804 114	6.51
1995	690	928.9	6 099 216	6.57
1996	885	888.0	5 942 269	6.69
1997	870	619.0	4 946 402	7.99
1998	774	666.7	5 274 173	7.91
1999	712	690.0	5 790 128	8.39
2000	709	688.5	6 363 915	9.24
2001	583	533.3	4 995 232	9.37
2002	545	562.0	4 954 629	8.82
2003	461	541.8	4 598 976	8.49
2004	408	612.3	5 317 027	8.68
2005	376	574.2	4 912 218	8.56
Average	653	670.2	5 333 192	8.10

Ten major groups of fish are included in this article: rockfish (family Scorpaenidae, comprising 45 different species), California sheephead (called "sheephead" hereafter, *Semicossyphus pulcher*), halibut (*Paralichthys californicus*), thornyheads (genus *Sebastolobus*), sablefish (*Anaplopoma fimbria*), cabezon (*Scorpaenichthys marmoratus*), lingcod (*Ophiodon elongatus*), eels (*Gymnothorax mordax*, *Anarrhichthys ocellatus*), surfperch (family Embiotocidae), and greenlings (genus *Hexagrammos*) (Table 2). Most live on or near the bottom and are considered groundfish or are nearshore species with limited migration. The majority are both — that is nearshore groundfish — making them good candidates for live harvesting with trap or hook-and-line. These groups represent the species most commonly targeted by live fish fishermen in California; live catches from other species groups are negligible. With the exception of halibut, thornyheads and sablefish, all are targeted in size for individual meal portions (i.e. plate-sized). Halibut, thornyheads and sablefish are landed live for the fresh fish market and are usually not targeted in size for individual restaurant portions. Although there are many species in California's commercial live fish fisheries, for the purpose of this article, live fish refers to finfish (vertebrates) only.

Data from the California Department of Fish and Game's (CDFG) California Fisheries Information System (CFIS) landing receipt database were used for all analyses presented in this article. The database includes receipt data from transactions at the first point of sale. Buyers are required to complete and submit to the CDFG receipts for all such transactions that take place in the state. Although these landing receipts indicate whether a given landing comprised live or dead fish, those indications are not reliable. In order to estimate quantities of live fish landings from the landings data, prices were used to differentiate between the two products. Since the prices paid for live fish tended to be substantially greater than for dead fish (from two-fold to many-fold, depending on species, condition and size), the price distributions from landing receipt data were analyzed to determine a threshold price that could be used to distinguish live from dead catch for each of the ten harvest groups examined here. Landing weight, gear types and personal communication with the fishing industry were also considered in order to characterize live catch. Due to complexities involved in determining live landings, including variability in prices, all numbers reported here should be viewed as approximate.

Table 2. Average annual commercial landings in California of the top live fish species groups, 1994–2005.

Harvest group	Average annual landings (t)
Rockfish	269
Flatfish	100
Thornyheads	82
Sheephead	67
Cabezon	54
Sablefish	39
Lingcod	36
Perch	17
Greenlings	6
Eels	1

Southern California's live fish fishery is dominated by rockfish, halibut, thornyheads and sheephead (Table 3). One of the few members of the wrasse family (Labridae) on the Pacific coast of North America, sheephead (Fig. 2), is a protogynous hermaphrodite (Love 1996). Sheephead begin their lives as females and after maturing, most, if not all, change sex and become males. These are very colourful and unique looking fish that, according to one high-volume dealer from southern California, resemble a food fish favoured in parts of Asia (Palmer-Zwahlen et al. 1993). This resemblance probably explains why California's live fish fishery started with trap-caught sheephead bound for California's ethnic Asian market.

One of the major concerns with sheephead and other species targeted in live-fish fisheries has been that the market demand is for single serving-sized fish, approximately 0.5–1.0 kilograms (kg) in size (McKee 1993). It is likely that most, if not all, sheephead of this size are females, including some that are reproductively immature (Tegner and Dayton 1997). The repercussions of such a fishery are that targeting the female reproductive potential could lead to depletion over a much shorter time than for fish without such life history characteristics. Similar concerns about overfishing have been expressed on the other side of the Pacific Ocean for another member of the Labridae family, the humphead wrasse or Maori wrasse (*Cheilinus undulatus*), a large coral reef-associated fish with similarities in sexual development.

Figure 2. Male (top) and female morphs of California sheephead (Photo: David Ventresca, CDFG).

Regulations that limit the total allowable annual commercial catch of sheephead went into effect in 2001 and may partially explain the decline in catch in recent years, but there is evidence that the average size and availability of this species were on the decline prior to 2000 (Alonzo et al. 2004). The catch of live sheephead has diminished nearly every year since its peak of 112 metric tonnes (t) in 1997. In addition to total allowable catch restrictions, sheephead (regardless of whether landed dead or alive) are managed by CDFG through minimum size limits and by limiting the number of participants allowed in the commercial fishery. CDFG has also considered various slot size limits (i.e. both minimum and maximum size limits) and different seasonal options for the fishery.

In 2004 the first ever stock assessment was completed for sheephead and the stock size was found to likely be less than 50% of its unfished size (Alonzo et al. 2004). Consequently, stepwise reductions in the allowable annual state-wide commercial catch have been established, starting with 34.1 t

Table 3. Commercial landings in southern California of the top 10 live-landed harvest groups, 1994–2005.

Year	Cabezon		Halibut		Lingcod		Rockfish	Sheephead			Total
		Eels		Greenlings		Perch		Sablefish		Thornyheads	
1994	4.9	3.7	43.3	trace	1.3	0.1	194.2	33.5	83.8	21.2	386.0
1995	3.5	3.1	74.2	trace	1.1	0.0	180.3	1.5	86.3	21.6	371.7
1996	7.9	2.2	78.9	0.4	1.9	0.1	142.0	0.0	84.3	22.5	340.2
1997	9.6	1.6	77.1	0.1	2.3	0.3	80.8	0.1	112.2	30.0	314.1
1998	14.1	1.4	64.3	0.0	3.7	0.3	106.1	0.1	95.3	25.8	310.9
1999	11.1	0.3	101.2	trace	2.0	0.3	84.2	1.5	51.7	36.6	288.9
2000	17.4	0.9	96.6	trace	1.1	1.2	58.9	0.8	64.3	54.3	295.5
2001	9.5	0.1	86.8	trace	1.5	0.2	54.7	1.4	52.5	65.8	272.4
2002	5.0	0.5	100.3	trace	1.8	0.8	48.9	6.9	46.0	82.6	292.9
2003	4.3	0.4	74.5	trace	2.8	1.4	32.1	5.3	43.5	126.4	290.7
2004	3.9	0.4	99.4	trace	3.1	4.9	39.5	6.5	37.1	131.5	326.2
2005	1.5	0.3	66.6	trace	1.8	2.6	29.2	10.8	38.1	134.6	285.5
Average	7.7	1.2	80.3	trace	2.0	1.0	87.6	5.7	66.3	62.7	314.6

Note: "trace" indicates landings of less than 0.05 t.

in 2005 and leading to an allowable catch of 12.8 t in 2008. The 2004 stock assessment results will be used as a baseline for comparison with future stock assessments and will be valuable in gauging the success of current rebuilding efforts.

California halibut is in high demand by sushi restaurants and is worth more when landed live. In 1999, halibut overtook rockfish and sheephead as the group with the greatest amount of live-catch for southern California. However, from 2002 onward, thornyheads has been the dominant group in the catch south of Point Conception. The thornyheads catch has increased in nine of the last ten years, going from approximately 21 t in 1994 to 135 t in 2005 (Table 3). The top five (by weight) harvest groups landed by weight in southern California in 2005 were, in descending order, thornyheads, halibut, sheephead, rockfish and sablefish.

In northern California the live fish catch has been traditionally dominated by rockfishes (Fig. 3), cabezon, and lingcod (Table 4). Sheephead are uncommon north of Point Conception. As with sheephead, the life history characteristics of rockfish also play a major role in the sustainability of the fishery, although in a much different way than for sheephead. In general, rockfish are relatively slow to mature and have a closed type of swim bladder (in which air cannot escape from the bladder through the mouth) that aids in swimming and energy conservation. The evolutionary advantage provided by having a closed swim bladder becomes a disadvantage to rockfish when they are brought to the surface from any depth greater than approximately 10–15 metres. The decrease in pressure in bringing a fish from deeper to shallower water can cause over-expansion of the swim bladder and has a suffocating effect on the fish. Because the survival rate of released fish is consequently low, minimum size limits on rockfish would be relatively ineffective as a management strategy.

Some species of rockfish live to an age of more than 100 years, although California's nearshore species have a shorter life expectancy. Studies of some nearshore rockfish species have shown that reproductive success increases with age and size (Berkeley et al. 2004) and rockfish are capable of reproducing throughout their adult lives. As with the sheephead fishery in southern California, removal of too many immature rockfish from a population before they have a chance to spawn can have a lasting effect.

The top five rockfish species landed live in northern California, by weight, in 2005 were, in descending order: black, brown (*Sebastes auriculatus*), gopher (*Sebastes carnatus*), grass (*Sebastes rastrelliger*) and black-and-yellow (*Sebastes chrysomelas*) rockfish, with combined landings of 113 t. The top five rockfish species landed live in northern California, by value, in 2005 were, in descending order: brown, gopher, black, grass and black-and-yellow rockfish, with a combined ex-vessel value of USD 1.1 million. In 1995, the top live-caught harvest groups from northern California, by weight, were rockfish, sablefish, cabezon, halibut and lingcod (Table 4). By 2005 the top groups had changed to rockfish, lingcod, halibut, sablefish and thornyheads.

Although seven species of rockfish have been declared overfished by the US federal government

Table 4. Commercial landings in northern California of the top 10 live-landed harvest groups, 1994–2005.

Year	Cabezon	Halibut		Lingcod		Rockfish	Sheephead		Total
		Eels	Greenlings		Perch		Sablefish	Thornyheads	
1994	18.2	1.3	32.7	0.7	19.6	36.5	212.6	28.5	1.2	0.6	351.9
1995	45.0	0.3	29.1	0.4	26.2	19.8	270.4	162.2	1.5	2.2	557.2
1996	62.6	0.3	26.0	1.4	33.8	14.9	293.2	113.4	1.2	1.2	547.8
1997	57.3	0.1	22.9	1.8	33.8	15.2	166.3	6.1	1.1	0.2	304.8
1998	95.5	0.1	12.4	5.5	40.6	20.2	168.7	1.3	0.7	10.8	355.8
1999	71.8	trace	16.0	12.5	55.8	6.6	187.5	1.9	1.1	48.0	401.1
2000	69.3	0.1	25.6	21.5	46.7	10.0	176.8	18.3	0.7	24.1	393.0
2001	37.4	0.1	10.2	9.2	20.7	9.3	145.2	9.2	0.6	18.8	260.8
2002	23.3	0.1	3.4	7.0	31.8	12.5	160.0	7.3	0.5	23.2	269.1
2003	23.6	trace	8.4	4.7	30.7	17.6	108.2	13.4	0.2	44.3	251.1
2004	28.4	0.1	25.3	1.8	35.9	20.1	136.3	5.8	0.2	32.3	286.0
2005	18.0	trace	29.8	1.6	31.8	9.8	146.4	26.2	0.3	24.7	288.6
Average	45.9	0.2	20.2	5.7	33.9	16.0	181.0	32.8	0.8	19.2	355.6

Note: "trace" indicates landings of less than 0.05 t.

Figure 3. Black (*Sebastes melanops*, upper left), blue (*Sebastes mystinus*, bottom left, middle and upper right) and copper (*Sebastes caurinus*, center) rockfish aggregation (Photo: Scot Lucas, CDFG).

(National Marine Fisheries Service), none of the most commonly live-caught rockfish species are among those. Of the top five live-landed rockfish species only gopher rockfish has been assessed within the last two years; it was found to have a healthy population (Key et al. 2005).

In 2002, as required by California's Marine Life Management Act, the CDFG drafted and the Fish and Game Commission adopted the Nearshore Fishery Management Plan (NFMP). One goal of this plan is to sustainably manage 19 of the nearshore finfish species, including 13 rockfish, found in California waters. Other goals include resource conservation, adaptive management, coordinated and cooperative approaches to management, incorporating socioeconomic dimensions into management, fair resource allocation, and evaluation of costs for management (California Department of Fish and Game 2002). An underlying principle of the NFMP is for CDFG to use a scientific approach to better understand and manage California's marine ecosystems through collaboration and coordination with fellow agencies and stakeholders. Due to increasing concern over diminishing fishery resources, the plan takes a conservative approach that reduces the overall take of the 19 nearshore species until sufficient scientific information became available to allow managers to set more informed catch limits. To implement the plan and meet total allowable annual catch limits for the state, as set by the federal government, CDFG developed a restricted access program. This program limits the number of participants allowed to fish commercially for nearshore species by issuing a limited number of permits. Seasons and depth restrictions may also be set to limit commercial take. California commercial permit holders are also subject to limits on the amount of catch allowed to be landed over a specified time period. An example might be 250 kg of cabezon over a two-month period per permit holder. This last management measure helps spread the catch between smaller and larger boats and was designed to help keep the season open longer. Catches over the course of a year are monitored using the CFIS landing receipt database (as well as other datasets). If the total allowable catch is met before the end of the year (or season), the fishery is closed until the next year or season. Much time is spent fine-tuning the number of permits and individual catch limits to achieve the goal of allowing fishing all year (or for the entire season if it is not a year-round fishery). As understanding of the resource status improves, a more liberal management strategy will be possible if stock assessments show healthy fish populations.

These management measures do not differentiate between the fisheries for live and dead product. However, to enable improved monitoring of the emerging live fish fishery, new commercial landing reports were introduced in 1994 that required differentiation between live and dead catch. Problems

with monitoring live catches have persisted for various reasons, including: miscoding or non-recording of live versus dead fish, unreported landings, misidentification of species landed, and difficulties in ensuring the accuracy of information recorded on landing receipts by buyers. Consequently, data on live landings entered into the CFIS database probably underestimate actual landings (which is why an alternative method of identifying live fish catches was used here), despite efforts at making landing receipt integrity a priority.

Eventually, the live fish fishery spread northward into the state of Oregon. The first significant live fish landings in Oregon occurred in 1997, with a reported total live fish catch of 42 t. By 2000, that number had almost doubled to 82 t (Bacon 2001), at least in part due to tighter restrictions in California's commercial fisheries. In 2002 an interim fishery management plan for Oregon's nearshore commercial fisheries was adopted and, similar to California's plan, reductions in commercial harvest were being achieved through trip limits and limited entry commercial permits (Oregon Department of Fish and Wildlife 2002). On 1 January 2000, the state of Washington, to the north of Oregon, adopted legislation to prevent a live fish fishery from developing in its waters (Washington Administrative Code). The legislation bans the transport of live fish. The state of Alaska, also seeing the live fish fishery expansion in states to the south (and to a lesser extent in British Columbia, Canada), took pre-emptive measures to stop the fishery from developing by enacting a state regulation barring commercial capture of groundfish that are intended to be kept alive (Alaska Administrative Code). This measure was undertaken for reasons of stock conservation. A lack of state personnel and other resources to monitor such a fishery also played a key role in the decisions to deter live fish fisheries in Washington and Alaska.

Other concerns related to live fish fisheries include some of the gear used to capture fish. In California, trap fishing for finfish evolved from market demand for live fish; this method also allowed fishermen to make use of lobster gear when the lobster season was closed. These traps are very efficient at catching fish but are not necessarily efficient at selecting target fish (Palmer-Zwahlen et al. 1993), and some species are heartier than others when it comes to surviving the rigors of being trapped and released. Therefore, there can be significant non-commercial and invertebrate bycatch in the live fish trap fishery, along with associated stress- and injury-related mortality of such bycatch. Also, abandoned or lost traps may continue to catch fish for extended periods of time until they decay and break down. Fish captured in these "ghost traps" may die from starvation or from injury sustained from attempting to escape. They in turn become bait, attracting other predators that get trapped. To alleviate the problem of ghost traps CDFG has put into its regulations a requirement that all traps used in any fishery must contain self-destruct devices designed to break the trap down rapidly enough to allow the escape of a substantial proportion of any fish that are trapped inside (California Code of Regulations, Title 14, Section 180.2).

Some of the initial concerns with the live fish fishery have been addressed through limits on both allowable take and number of participants. Trap design regulations have helped solve the problem of ghost trap fishing. However, issues that still persist include monitoring of bycatch, small target sizes and difficulties in monitoring landings. Small target size and bycatch are both characteristic of this type of fishery and any solutions, aside from shutting the fishery down completely, are complex and expensive from a management standpoint. Accurate information on condition (live or dead) of fish from landing receipts continues to be a problem as well. For example, in 2005, for the harvest groups examined in this article, more than 12,000 landings were made with unknown condition codes, totalling nearly 7000 t.

Overall, live fish fishing in California seems to have reached a modicum of stability, primarily through reducing the total allowable take. However, by most accounts it is still a data-poor fishery, especially with respect to bycatch and its mortality. Although most of the most commonly caught live rockfish are not considered overfished, they live in aggregations containing a complex of species. Therefore, there is the potential of bycatch mortality of some of the overfished rockfish species. Depth closures have been used most recently to offset this potential as the species of concern generally live in deeper water than the rockfish targeted in the live fish fishery. Future strategies for management in California include continued stock assessments and development of a coast-wide system of marine protected areas. Marine protected areas allow for a more ecosystem-based management approach as opposed to the species-by-species management approach that has been used most often in the past. Such protected areas may have a spill-over effect that helps to replenish areas that have been fished out.

With respect to the economics of California's live fish fishery, two patterns are clear: the overall number of fishermen participating in live-catch fisheries has dropped by a little over half since 1994, while the average price of live product has increased (Table 1). High demand for live fish persists.

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Validating camouflage grouper, *Epinephelus polyphekadion*, spawning aggregations: A preliminary study from Fiji fisher interviews

Yvonne Sadovy[1]

Reef fish spawning aggregations are exploited for both live and dead fish, for subsistence and, increasingly, for commercial use. In the Indo-Pacific, there are very few studies or long-term fishery datasets that provide information on the history and current status of exploited aggregations. Therefore, much use has been made of fishers' traditional and community knowledge to gather such information, following the pioneering work in this field by Robert Johannes (e.g. Johannes et al. 2000; Hamilton 2005; Hamilton et al. 2006; SCRFA country reports). It is important, however, to try to validate information from interviews to check species identifications and confirm sites and times of spawning. In doing so, it is important to work with local fishery officers and communities. It is also necessary to ensure the confidentiality of spawning site locations, at least until they are protected or managed, to safeguard them from further exploitation.

The following article is from newsletter # 8 (December 2005) of the Society for the Conservation of Reef Fish Aggregations (SCRFA), which has many more articles on spawning aggregations from around the tropics (see http://www.scrfa.org/server/whatsnew/newsletter.htm).

As part of an attempt to validate fisher interviews conducted by SCRFA in the western Pacific and Southeast Asia, a preliminary field validation was carried out in Fiji during the summer of 2005. Specifically, we wanted to confirm species, timing and locations of spawning aggregations of reef fish identified in interviews conducted since 2003.

Several fish species aggregate in large numbers in or near the channels and passes of Fiji's outer reefs for just a few months each year, although the timing for each species appears to vary substantially across the country. These species include several groupers, including camouflage grouper, *Epinephelus polyphekadion* (locally *kesala*), squaretail coralgrouper, *Plectropomus areolatus* (*batesai*), brown-marbled grouper, *E. fuscoguttatus* (*delabalea*), and the speckled blue grouper, *E. cyanopodus* (*raravuya*), as well as several other species such as a sweetlips, *Plectorhinchus chaetodontoides* (*sevaseva*), and emperor fish (Lethrinidae). Many of these species evidently spawn in large numbers at predictable locations, and have become severely reduced in the fishery as a result of fishing on those large aggregations. Between 2003 and 2005, interviews were conducted in a widely dispersed set of communities throughout the country to examine the status, species and history of exploited aggregations (see also the SCRFA database: http://www.scrfa.org/server/database/dbaccess.htm).

The validation study was conducted by interviewing fishermen in several different communities, and then by diving at four identified aggregation sites in outer reef channels during one of the identified spawning seasons. Catches on site were inspected and gonads examined, while fish traders in nearby urban areas were also interviewed. In 2003, interviews were conducted in fishing communities in Vanua Levu. In 2005, the same area was revisited during the reported spawning aggregation season and divers visited aggregation sites. The work was conducted in close collaboration with the Research Division of the Fisheries Department of Fiji's Ministry of Fisheries and Forests, and allowed us to confirm species identifications, aggregation condition, catch levels and gonad status at four aggregation sites during a key reported aggregation period.

The results of the 2005 summer visit confirmed the presence of camouflage grouper and squaretail coralgrouper, as indicated by previous interviews at reported aggregation sites. Observations of catches of these two species in the boats of fishers present at these aggregation sites also confirmed that these species were frequently caught, and were ripe and ready to reproduce. Small catches of other grouper species, such as *E. howlandi* and *E. cyanopodus*, were also observed, and individuals of these two species also had ripe ovaries.

1. Society for the Conservation of Reef Fish Aggregations (http://www.scrfa.org) and Department of Ecology & Biodiversity, University of Hong Kong, China. Email: yjsadovy@hku.hk

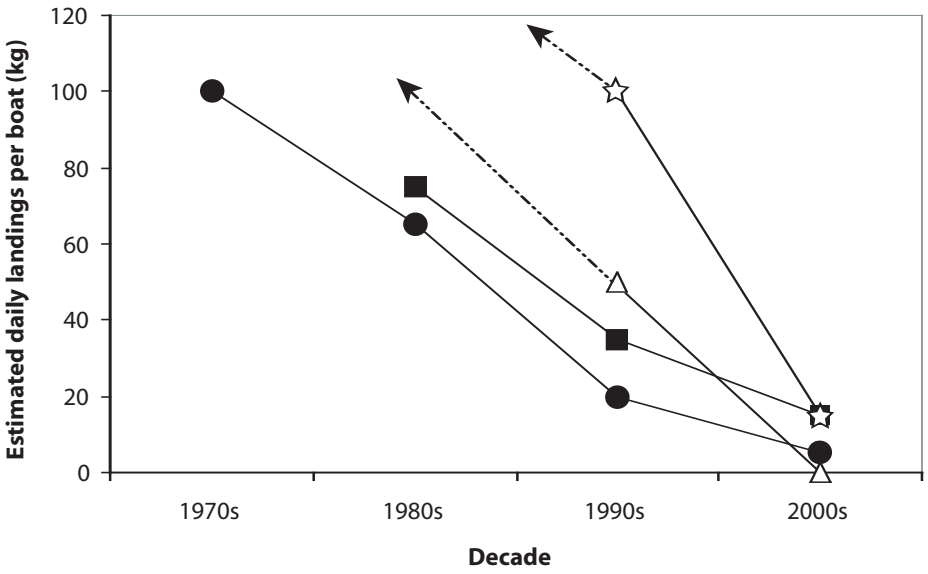

Figure 1. Camouflage grouper landings from four different aggregations in Fiji according to fisher interviews (2003–2005) and preliminary validation in 2005 (dash lines point backwards to decades when fishers reported "hundreds" of kg per trip). Each line represents a different aggregation site.

Overall, the results show classic signs of overfishing of aggregations and supported earlier interviews. From both the interview information, as well as from the on-site dives and catch inspections, it was clear that several aggregations of camouflage grouper, the species for which there is the most information, had probably been too heavily fished. During the 2005 summer visit, numbers of fish at aggregation sites were low, despite the time being a reproductive period; ripe fish, bulging with eggs, were seen at some of the sites and inspections of catches revealed many ripe gonads. Underwater observations of groupers at aggregation sites were fully consistent with the low numbers of fish being caught (i.e. low catch rates) by fishers during our visit, and with previous interviews. It is clear that there have been steady declines in catches of camouflage grouper at all aggregation sites surveyed, since at least the 1980s (Fig. 1). Catch rates are now very low compared with catch rates in the 1980s, sometimes with declines of 70% or more. One site in particular (white triangles in Fig. 1), previously reported to have been very productive for camouflage grouper, had no fish, and no fishing boats were on the site despite the excellent weather. Indeed, the nearby community in whose traditional fishing area (marine tenure system, known as *qoliqoli*) the aggregation site was located is so concerned over declines in recent years that they are discussing the possibility of establishing a fishing ban at the site.

The declining trends are also fully consistent with the information provided by two major traders/middlemen based in a nearby urban centre. About 200 boats now fish commercially for grouper along the Great Sea Reef during the aggregation season, according to middlemen, and this is at least 10 times more boats than 15 years ago. Moreover, to maintain catches to meet demand, boats now travel farther and spend more time at sea. All indicators are that the reef fish fishery, in general, is considerably more heavily fished compared with a decade or so ago, and that current levels of fishing pressure have caused serious declines in at least one species, the camouflage grouper, at all four studied aggregation sites.

Because a large proportion of annual landings of camouflage grouper was reported to be taken at spawning aggregation times, SCRFA submitted several recommendations to the government:[2]

- Facilitate community management of *qoliqoli* to protect aggregation sites from overfishing (e.g. reduce fishing effort on aggregations by com-

2. The results of this study were also presented and discussed at a workshop on reef fish fisheries held in July, 2006, in Suva (see article by Sadovy and Batibasaga, p. 38–39, this issue). The Minister of Fisheries and Forests gave the opening speech and called for much greater attention to be paid to managing reef fisheries in Fiji. The workshop was co-organised by SCRFA and Fiji's Fisheries Research Division.

munity regulations; reduce number of licenses issued, etc.), with government assistance for development of management plans and enforcement.
- Prohibit commercial use — including the purchase by government ice plants — of fish from spawning aggregations, and prohibit fishing by non-community members.
- Undertake educational initiatives to explain to communities why fish numbers are declining and what options are available to halt declines.
- Incorporate spawning aggregation sites in ongoing marine protected area designations.
- Prohibit night-diving, or diving with compressed air, on aggregations.

Summary

Fishers in fishing communities have a wealth of knowledge about their local fishery and its history. Interviewing fishers can be an effective way to compile such knowledge, and spawning aggregations, because they are so distinctive, lend themselves particularly well to the interview approach. However, validation of collected data with first-hand observations is advisable, whenever possible, to ensure the best recommendations for management, and great care is needed in collecting and interpreting data. As one example from our Fiji work, we found that *E. howlandi* (*varavara*) also aggregates at some of the sites, but in shallow areas. Since our original interviews had not included fishers working in shallow waters, interviews did not record this as an aggregating species. Poorly applied (i.e. by insufficiently prepared workers or poorly designed questionnaires), the interview approach can be a waste of time and effort or could lead to inappropriate or insufficient protection. As another example, interviews in Palau did not identify all aggregation months for certain groupers (subsequently identified by detailed field work), thereby resulting in insufficient management protection (Johannes et al. 1999). It is clear from my own experiences, as well as those of others who have conducted interviews, that familiarity with local fish species and fishing practices is essential to gain the respect and interest of interviewees. It is also important to ensure that questions are unambiguous and reasonable, and to examine responses for consistency among respondents. Importantly, interview occasions should be used to transfer information on exploited species back to communities. The confidentiality of aggregation site locations should also be maintained.

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The live reef food fish trade in Fiji[1]

Ledua Ovasisi[2]

A brief history of the trade in Fiji

Fiji is one of the countries in the Pacific that has recently become involved in the live reef food fish (LRFF) trade. The trade was introduced by the government in the late 1990s through the Ministry of Agriculture Fisheries and Forest (MAFF) Commodity Development Framework (CDF) programme.

The objective of the CDF programme was to strengthen export-driven and import-substitution commodities. The LRFF trade was identified as one of the main export commodities under the programme. The programme was divided into two main sub-programmes reflecting the archipelagic zoning of the country. The main sub-programmes are the offshore fishery, which deals with the tuna/snapper industry, and the inshore fishery, which deals with the harvesting of resources within coastal waters.

The government anticipated that the introduction of the LRFF concept to communities would result in the realisation of economic development and the opportunity for a better living standard due to the higher potential for earnings from exporting reef fish live, compared with the sale of dead fish to local markets. For instance, approximately 338 tonnes of coralgroupers (*Plectropomus* spp.), cod (*Epinephelus* spp.) and wrasse (Labridae), valued at 1.35 million Fijian dollars (FJD)[3] in the local markets, are caught in the Bua and Macuata coastal zone annually. These fish are sold to the Labasa and Suva markets. Exporting the same amount of fish to Asian markets (live) would realise an annual export earning of well over FJD 16.9 million.

LRFF development started with one pilot company and later increased to eight companies. Most of these have subsequently withdrawn and opted to move out of Fiji for the following main reasons:

- LRFF is a new concept and will take a long time for members of communities to adapt to the commercial demand of the trade.
- Fiji has 410 "customary fishing rights areas" managed by the Fisheries Department, with 25 Fisheries Stations and 17 ice plants located within the four administrative divisions (east, west, north and central). Most communities were too focused on selling their catch through the rural fisheries service centres.
- The LRFF trade targets only a few species, so other fish caught are discarded or considered only for subsistence consumption.
- Cargo space for exporting is limited due to high competition from other fisheries commodities, such as tuna.
- The geographical set-up of some highly reliable targeted areas is too costly for operators in terms of their remoteness (e.g. the Southern Lau group).

From late 2002 until early 2003, only two companies were operating: Satseas Company Ltd in Bua (Northern Division), and Atlas Ocean Products Ltd (Southern Lau).

Actual breakdown of companies

Satseas Company

- Operation site in Bua (Islands of Galoa and Tavea)
- Deployed fish cages
- More than 40 fishermen actively participated in the fishing operation
- Mother vessel collected fish and transported to Viti Levu (Western Division) for export

Atlas Ocean Products

- Based in Suva
- Operation site in Southern Lau

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2. Ministry of Fisheries and Forests, PO Box 2218, Suva, Fiji. Email: lovasisi@fisheries.gov.fj
3. FJD 1.00 = USD 0.59 (December 2006)

- Deployed fish cages
- An average of 40 fishermen from each village actively participated in the fishing operation; fishing was done rotationally, one island after another (Lakeba, Oneata, Komo, Namuka and Vanua Balavu)
- Mother vessel collected fish and transported to Viti Levu (Suva) for export
- Company also bought fresh dead reef fish

Only local fishermen were allowed to catch fish; operators or companies were restricted to purchasing the fish, as outlined in the management guidelines.

The buying prices ranged from FJD 5.50 to 6.00 per kg for humphead wrasse (or Maori wrasse) (*Cheilinus undulatus*) and FJD 4.50 to 5.00 per kg for coralgroupers (or lower, depending on the fish quality). These buying prices were fixed as part of the agreement between the custodians, operators and Fisheries Department.

Fish bought from local fishers usually passed through several levels of trade right up to the market. Market prices often changed and the trade fluctuated depending on fluctuations in market price. So, the trade may have sometimes disadvantaged local fishers due to the fixed buying prices. Fishermen may have received very little for their fish even though actual market prices may have been very high.

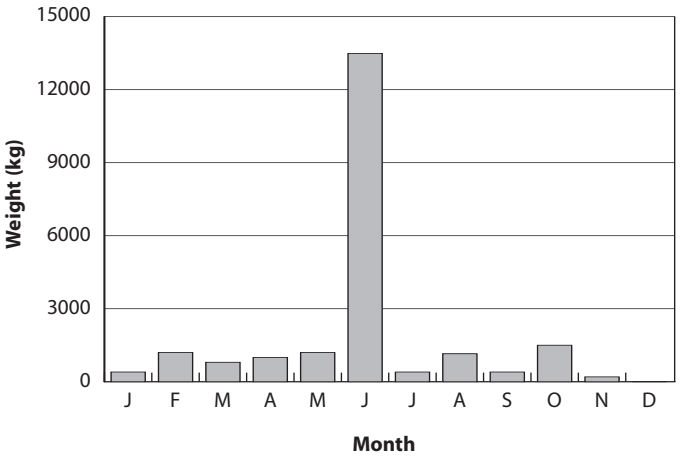

Figure 1. Live reef food fish exports from Fiji (2003).

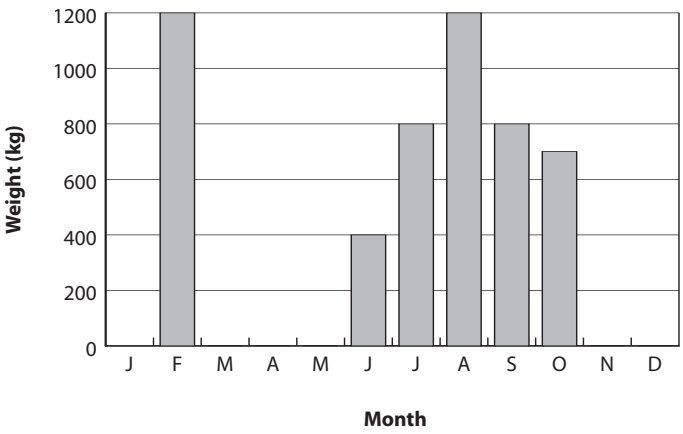

Figure 2. Live reef food fish exports (2004; excluding November and December).

Export of live reef food fish

Satseas Company

- Satseas Company exported cod (*Epinephelus* spp.) and coralgroupers (*Plectropomus* spp.)
- The company exported 8250 kg of live fish in 2003, valued at about FJD 410,000
- The company exported 5100 kg of live fish in 2004 (excluding November and December), valued at about FJD 255,000

Atlas Oceans Products

- Atlas Ocean Products started a live fish operation in 2003 and exported once that year, with a shipment of 13,000 kg, valued at about FJD 650,000. In Figure 1, the high value in June is due to this shipment and 400 kg exported by Satseas.

For the above breakdown, the market prices were obtained from the ADB booklet "While stocks last: The live reef food fish trade" (Sadovy et al. 2003).

Figure 2 shows a decrease in exports because only one company was operating. Satseas only exported once in the first five months of 2004 (in February), as the company ceased operation to renew cages. Operations started in June with the exportation of 400 kg, at which point a new company (King Fisheries Limited) took over.

Status of the live reef food fish trade

King Fisheries Limited (KFL) is the only company operating a LRFF enterprise. KFL is a locally registered company with foreign shareholders. It is based in Nadi with a warehouse/processing factory close to the airport. KFL began operating in late June 2004, taking over from Satseas following the approval given by the Fisheries Department to export both live and dead reef fish.

The company's operational site is Bua, mainly in the *qoliqoli* (fishing ground) around the island of

Tavea. This followed approval granted by the Buli Lekutu (Paramount Chief in Bua) to access the *qoliqoli*. The island of Tavea is one of the leading areas for the LRFF trade. It was also targeted by Satseas after the company moved from Galoa Island. Tavea has considerable potential, with close to 50 fishermen actively involved in the live reef food fishery. These fishermen are well known for their fishing skills and knowledge, being the traditional fishermen of the Buli Lekutu. KFL has set up fish cages with assistance from the fishermen.

The fish cages have a holding capacity of 500 kg of live reef fish (Fig. 3). Three pens are held together to form a large cage of three separate compartments. The cages are all the same size (about 8 m in length by 6 m in width). The fish cages have been renewed to keep fish safe from shark attacks, damage from bad weather conditions, and other factors that may lead to high fish mortality.

The cages are located in front of the village, visible from the shore for security. While fish are in captivity, they are left to feed naturally without the provision of feed.

In a similar way to the operation in Lau and other LRFF operations, the mother vessel tows the fishing boats (dories) out to the reef or fishing locations where the boats disperse to their preferred fishing sites. According to the fishermen, the number of boats has increased from 14 at the beginning of 2004 to 16 boats. Fishermen operating in the LRFF trade can earn an average of FJD 300 to 700 per week depending on the catch landed. This has enabled these fishermen to improve their standard of living.

Once fish are purchased, they are shipped to Nadi via the mother vessel, where they are kept, processed and exported to overseas markets. The company has been exporting every week, with an average shipment of 180 kg, valued at FJD 1260.

Management and challenges

The Fisheries Department, in facilitating the development of the LRFF trade in Fiji, has developed some guidelines to help ensure the long-term sustainable development of the industry. These guidelines will be reviewed throughout the year, then finalised and documented by December 2005. The guidelines are as follows:

- All companies must have an indigenous Fijian partner as a 51% shareholder.
- Fijian protocol must be followed, with permission to be granted by the traditional custodians followed by approval from the Provincial Office. Original copies of all formal agreements must be submitted to the Fisheries Department.
- A baseline assessment survey should be carried out in the area targeted for operation to assess the availability of target species; viability of the business and the total allowable catch that can be taken without compromising resources for the future. The survey is to be fully funded by the operator or company.
- The vessel is in no way to participate directly or indirectly in the taking of fish (as defined under the Fiji Fisheries Act, Cap. 158) either for subsistence or commercial fishing. Fishing may only be done by the resource custodians, so foreigners or non-citizens should not be involved in catching fish, except for training purposes. The fisheries observer on board will ensure this condition is met.
- Wild species such as humphead wrasse should not be considered a target species in this fishery and no company, organisation or individual should export this species under the live fish trade.
- Companies must only engage in the LRFF operation and no other marine resources should be taken or purchased by them.
- Fishing of targeted species is not permitted during spawning or aggregation periods.
- The companies' warehouses and fishing vessels must be accessible to the LRFF project officer and enforcement officers for monitoring and inspections, as appropriate.
- All export of live reef fish should be carried out from designated ports, where fish can be inspected before being exported to overseas markets.
- Shipment of live reef fish to overseas markets by sea is not permitted. All live reef fish exports should be by airfreight.
- Licenses will be reviewed each year.

Figure 3. Live reef food fish cages on the island of Tavea (photo by Ledua Ovasisi).

The Fisheries Department sets out agreements with the company/operator prior to operation. The agreement mainly focuses on the terms of operation (enforcing fisheries regulations) that the company must comply with; any breach of the agreement will incur a penalty or automatic cancellation of the operation.

The Fisheries Department is working on enforcement and monitoring with recruitment of field officers to be based permanently in the field/village or operations site to collect operational and domestic (subsistence) data which would then be analysed to check on the amount of targeted fish species harvested in a week or month.

The following monitoring system checks are currently in use:

- A fisheries project officer boards the company vessel to monitor operations on site and the vessel's overall operational system.
- Site visits are made and regular meetings with fishers are held to monitor the benefits and impacts of the trade and to facilitate the development of the trade.
- Visits are made to companies to collect data, inspect the processing facility and discuss other relevant activities of the industry and the Fisheries Department's work programme.
- Companies submit data on a monthly basis to the Fisheries Department, as outlined in the agreement.

Conservation measures

- Conservation of marine resources: the operation is restricted to the purchase of fish only (mainly live reef fish and sometimes fresh dead reef fish). There is ban on targeted species such as humphead wrasse (*Cheilinus undulatus*), which is also included in the CITES Appendix II.
- Marine protected areas (MPAs) are implemented in areas highly targeted by the trade to allow target fish species and other marine resources to breed.
- Fish aggregation devices (FADs) are deployed in areas where the trade is operating to attract offshore fish species and to substitute for reef fish taken out by the trade.

Major challenges for the LRFF trade

- Monitoring of operations (as described above), including linkages between the site, company factory and port to the overseas markets.
- Stock assessment surveys, which take a long time and may be too expensive.
- Educating (raising awareness of) the communities on all aspects of the LRFF trade.

Future directions of the trade

The development of the LRFF trade in Fiji is not consistent, judging from the number of operators/companies entering and leaving, as highlighted earlier. The Fisheries Department is aware of the fluctuations in the trade but recognises the benefits that it has brought to local communities in the short time it has been operating. The Department views the trade as an income generating activity, but recognises that the benefits have often come with high costs.

The Fisheries Department is optimistic that, with good facilitation and monitoring, the trade can be considered as one of the best alternative sources of income for coastal maritime communities. The Department is considering changes in its fisheries activities, such as shifting the LRFF project to its research division, as it involves a lot of research activities on both target and non-target species, impacts of the trade and fishing operations on the environment, including comparisons of LRFF target and non-target sites and the near extinction of marine species such as humphead wrasse *(Cheilinus undulatus)*. This research is important given the number of companies expressing interest in being involved in the trade and will help the Department to determine the real depth of the trade, the status of its available stock and its economic value and benefits. With this information, the Fisheries Department will be in a better position to determine the future of the LRFF trade.

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A socioeconomic perspective on the live reef fish food trade for small-scale artisanal fishers based on case studies from the Pacific[1]

Mecki Kronen[2], Samisoni Sauni[2], Lilian F. Sauni[2] and Aliti Vunisea[2]

This summary highlights some of the economic and social aspects of small-scale artisanal reef fisheries (SSARF) in Pacific Island countries (PICs) that need to be taken into account if a shift to a commercial fishery, such as the live reef fish for food (LRFF) fisheries, is to be considered. These observations are based on experiences gained during field surveys on the current status of reef fishery resources in PICs[3].

The LRFF trade is one of the emerging fisheries that may add value to the region's reef resources and is considered as an attractive income generator for coastal communities in PICs. Case studies presented in Annex I illustrate that the LRFF trade may offer between three and five times the revenues that small-scale commercial reef fisheries generate. While an initial assessment of the opportunity to generate the much needed cash may be appealing, the introduction of a new fishery must take into account possible detrimental effects to the resource and the socioeconomics of the communities concerned. Some of the risks presented here are not restricted to the LRFF trade only. Many factors of concern discussed below also apply to other emerging small- to medium-scale commercial coastal fisheries in PICs, such as the aquarium fishery, beche-de-mer, and live rock and coral harvesting. The factors that are likely to be common across these various commercial fisheries have been used for a qualitative comparison of their likely magnitude of impact as presented in Annex II.

In terms of the LRFF trade, factors that need to be considered include:

- The LRFF trade is generally very selective in terms of target species and often targets spawning aggregations. The target species are also generally important fish for local communities. The sustainability of fishery productivity, and the impact of the possible resultant competition for species that are an important food species for the local community, need to be assessed.
- The LRFF trade is a commercial fishery but all members of the community may not be able to participate or benefit. This may result in detrimental social changes as there is a risk of inequities between groups in the community who do or do not have access to this fishery. This can lead to disputes and/or conflicts with regards to distribution of income, job opportunities, etc., from customary marine tenure (CMT) areas leased to the fishery.
- It is found to be the case that fishers who participate in the LRFF trade often abandon fishing for subsistence (home consumption). This pattern, coupled with increased cash income, may alter consumption patterns in favour of processed (i.e. tinned) imported goods, and create a burden of debts if the income flow is not continuous and does not support the increased household expenditure level. This may increase pressure on the social "share-and-care network" within a community.
- The LRFF trade is likely to be mainly – if not exclusively – participated in by men. The issue of gender participation in fisheries, including possible gender inequities with regard to access to the resource, equipment and in particular, changes in access to income, needs to be considered.
- Participation of community members in the LRFF trade may require them to obtain motorised boats and specialised equipment. While the necessary investment costs are usually met by the entrepreneur, instalment payments for boats and equipment are generally expected to be made by participating fishers, who will own these amenities in the long term.

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2. Reef Fisheries Observatory, BP D5, 98848 Noumea Cedex, New Caledonia. Email: MeckiK@spc.int
3. The Coastal Component of the European Union (EU) 8th and 9th European Development Fund (EDF) funded Pacific African-Caribbean-Pacific States (ACP) and the French Overseas Countries and Territories (OCT) Regional Oceanic and Coastal Fisheries Development Programme (PROCFish) is undertaking a comparative assessment of the status of reef fisheries, both resource and socio-economic, and development of indicators to assist future monitoring.

This arrangement involves risk of financial dependency and may influence local decision making regarding exploitation of resources, possibly leading to overexploitation (Hollup 2000).

- The LRFF trade is an export fishery, therefore the market is determined by external factors that drive demand and influence profit margins. The market can therefore fail due to political and/or economic situations external to and beyond the influence of the participating communities.
- The long-term success of the trade will also depend on the participation of local communities and fishers for whom catching fish to keep alive for market is a new concept. Because the participating communities lack experience, skills training may be required to equip community members and fishers accordingly.
- The LRFF trade generally requires licensing in most PICs. However, responsibilities for licensing, monitoring and compliance may be spread over a number of different governmental and non-governmental bodies. For instance, in the case of the aquarium trade industry in Vanuatu, foreign investors are required to have approval, and need to register with the Vanuatu Investment Promotion Authority (VIPA). Three distinct levels are involved as regulatory and management authorities, including the national government (VIPA, Department of Fisheries and the Environmental Unit for CITES), the provincial governments (six in total), and the resource owners under CMT (Hickey 2002). While such instruments aim to properly establish effective and efficient monitoring and surveillance mechanisms, insufficient technical expertise or management capacity, and confusion due to the various authorities involved, are major constraints in achieving sustainability of the trade.

Taking into account the above arguments, we would like to highlight three major socioeconomic aspects that need to be considered for the introduction of the LRFF trade from the participating fisher and resource owner community's point of view.

Monetary and non-monetary resource values

While it is true that coastal communities in PICs are increasingly moving to a cash-based economy, the communities where reef fisheries play an important economic role (both subsistence and cash) and which are potentially targeted for the LRFF trade are generally still more traditionally oriented. The introduction of a commercial fishery such as the LRFF trade often introduces a monetary value for the community's marine resources. Such new cash values may co-exist with, but at times can also compete with and impact on, the traditional social processes inherent in a traditional social system (reciprocal exchange system), such as contributions to food security, maintenance of networking and social coherence amongst community members, and the strengthening of social institutions (Iwariki and Ram 1984; Kronen 2004). In other cases, conflicts arise in fishery resource ownership, access rights, access fees and general jurisdiction over areas leased out to companies. Consequently, the risk of reducing social coherence and resilience in target communities should be considered.

Figure 1. A fisherman in the Lau Group, Fiji, uses a wooden boat equipped with a 30 horsepower outboard engine and appropriate store facilities provided by the local LRFF agent to pursue traditional fishing during absence of the LRFF mother boat (photo by Mecki Kronen).

Cost–benefit analysis (needs, risks and opportunities)

The need to generate income may be seen in relation to the current lifestyle and weighed against the productivity, viability and lifespan of a new commercially oriented fishery such as the LRFF trade (Adams 1998; Foale and Day 1997; Kinch 2002; Foale and Manele 2003). The socioeconomic consequences, and also the risk of detrimental and usually long-term ecological effects (Adam et al. 1997; Selvam and Ramasamy 2000; Krishnan and Birthal 2002), of fisheries that may only pro-

vide immediate or short-term wealth to a community need to be considered and compared to other fisheries and/or income alternatives. Promoting and introducing a fishery opportunity that needs a relatively high investment, given the usually cash-poor situation of most rural communities in PICs, may create "a culture of dependency" (Sauni et al. in prep.). Thus, a community may be forced into harvesting marine resources increasingly for export, or to collect and sell non-target species in exchange for a lifestyle of less quality (nutrition), higher dependency and reduced social coherence (Fitzhugh 2001).

Figure 2. Traditional paddle outrigger canoe used by fishermen on Efate, Vanuatu (photo by Mecki Kronen).

Figure 3. Traditional sailing outrigger canoe used by fishermen in the Maskelynes, Vanuatu (photo by Mecki Kronen).

Sensitivity analysis regarding sustainability and social and economic viability

The LRFF trade often involves the leasing of reef areas without properly defined boundaries, which increases the potential for conflicts and disputes in CMT areas. Principles such as benefit sharing, equity in access or use of land and sea resources are fundamental to traditional social networking and security (Taylor and Singleton 1993; Aswani 2002). Thus, there are possible effects of commercial fisheries such as the LRFF trade to be taken into account as they may provide economic benefit to a few individuals or families through use of common resources that also support the livelihood and food security of the entire community. The terms of the trade (and associated level of harvesting) are primarily determined by the export company (based on the principle of profit maximisation), with little attention paid to the sustainability of the resource. Local partners also run the risk of companies pulling out in the advent of the application of stricter environmental controls, customs regulations or application of management policies.

The above points are just some of the significant factors that should be taken into account by decision-makers and community leaders where a move from subsistence to one of these small- to medium-scale commercial fisheries is under consideration.

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Annex I. Case studies comparing possible gross revenues (in USD/hour of fishing time) from small-scale commercial and small-scale traditional fisheries in selected communities of Fiji, Kiribati and Vanuatu.

a) Comparison of the LRFF trade and small-scale traditional fin fisheries in the Lau Group, Fiji.

	LRFF trade Lau Group Fiji presence of mother boat	LRFF trade Lau Group Fiji absence of mother boat (middleman)	Small-scale traditional fin fisheries Lau Group Fiji
Average fishing time (hr)	49.5 (per week)	6 (per week)	654 (per year)
Average catch (kg)	345 (per week)	30 (per week)	1,293 (per year)
Price (USD/kg)	1.66	1.48	1.18 (average)
Total revenues (USD)	571.68 (per week)	44.39 (per week)	1530.40 (per year)
Revenue (USD/hr-fished)	11.55	7.40	2.34

The Lau Group case study is based on average figures from interviews conducted with 25 small-scale traditional fishers (four of whom also participated in the LRFFT fishery) in Nukunuku village, within the framework of the DemEcoFish/PROCFish/C project, Secretariat of the Pacific Community, September 2002 (FJD-USD exchange rate: 0.59180).

b) Comparison of live coral and rock extraction fishery and small-scale traditional fin fisheries in Muaivuso, Fiji.

	Live coral and rock extraction fishery Muaivuso Fiji	Small-scale traditional fin fisheries Muaivuso Fiji
Average fishing time (hr/week)	20	25
Average revenue (USD/week)	10.36	11.84
Revenue (USD/hr-fished)	0.52	0.47

The Muaivuso case study is based on average figures from interviewing 28 households in August 2002 within the framework of the PROCFish/C project, Secretariat of the Pacific Community and collection of

complementary information on live coral and rock extraction fishery only in May 2003. Details of the Muaivuso case study are given in Sauni et al. (in prep.) (FJD-USD exchange rate: 0.59180).

c) Comparison of the aquarium fish trade and small-scale traditional fin fisheries in Christmas Island, Kiribati.

	Aquarium fish trade Christmas Island Kiribati	Small-scale traditional fin fisheries Christmas Island Kiribati
Average fishing time (hr/year)	312	800
Average catch	flame angel: 20 (specimens) lemon peel: 20 (specimens) gold flake: 1 (specimen) blue tang: 20 (specimens)	2300 kg
Price (USD)	flame angel: 1.00 (per specimen) lemon peel: 0.80 (per specimen) gold flake: 10.00 (per specimen) blue tang: 2.00 (per specimen)	0.50 (village)
Total revenues (USD/year)	4128.00	1150.00
Revenue (USD/hr-fished)	13.23	1.44

The Christmas Island case study is based on average figures from three aquarium fishers and 21 small-scale traditional fin fishers interviewed in Tabakea, August 2004, in the framework of PROCFish/C project, Secretariat of the Pacific Community (AUD-USD exchange rate: 0.75979).

d) Comparison of beche-de-mer fishery and small-scale traditional fin-fisheries in Moso, Vanuatu.

	Beche-de-mer fisheries Moso Vanuatu	Small-scale traditional fin fisheries Moso Vanuatu
Average fishing time (hr/year)	120	128
Average catch (kg/year)	lolifish: 50 greenfish: 50 others: 150	320
Price (USD/kg)	lolifish: 1.65 greenfish: 2.75 others: 3.66	1.83 (village)
Total revenues (USD/year)	769.44	586.24
Transport cost to Port Vila	36.64	–
Revenue (USD/hr-fished)	6.11	4.58

The Moso case study is based on average figures from beche-de-mer and small-scale traditional fishers interviewed on Moso Island, October 2003, within the framework of the PROCFish/C project, Secretariat of the Pacific Community (VUV-USD exchange rate: 0.00916).

Annex II. Selected factors to compare the LRFF trade to other commercial and small-scale artisanal reef fisheries (0 = lowest, 3 = highest).

Parameter	LRFF trade	Aquarium trade fisheries	Live coral & rock fishery	Beche-de-mer fishery	Reef fishery
Selection of target species	3	3	3	3	1-2
Target species are also used for subsistence	1-2	0	0	1	3
Income opportunities	3	3	2-3	3	2
Catch may be used in non-monetary exchange	1-2	0	0	1	3
Gender involvement	men	men	men/women	men/women	men/women
Investment needs	3	3	1	1 (3)	1-3
Special skills needed	2	3	1	1 (3)	1-3
Dependency on a particular marketing network	3	3	2	2	1
National market demand	1	0	0	1	3
International market demand	3	3	3	3	1
Licensing requirements	3	3	3	3	1

Reef fishery workshop held in Fiji

Yvonne Sadovy[1] and Aisake Batibasaga[2]

A conference and workshop entitled "Reef fisheries: Now and for the future" was held in Suva, Fiji, in July 2006, as a collaborative effort between the Fisheries Research Division of the Fiji Fisheries Department, and the Society for the Conservation of Reef Fish Aggregations (SCRFA). It was the first meeting to focus on coral reef fisheries ever held in Fiji. The objectives were to 1) gain an overview of the history, current status and issues of coral reef associated fisheries in the western Pacific region, including Fiji; 2) review management, development and other initiatives in place or planned in Fiji of relevance to coral reef associated fisheries; and 3) identify information and management gaps that must be addressed to better achieve sustainable exploitation of coral reef associated fisheries in Fiji.

More than 50 participants from a wide range of communities from throughout Fiji were invited to represent their respective institutions and communities, and to bring their experiences and concerns to the meeting. The workshop was opened by the Minister for Fisheries and Forests, followed by two days of presentations and workshop sessions, conducted in both Fijian and English. Following the workshop, a summary of the major outcomes was presented to the Acting CEO of the Ministry of Fisheries and Forests, Ms Alefina Vuki.

There was a broad consensus that there were widespread declines in Fiji's reef fisheries, with negative consequences for poverty alleviation, social stability and food security in coastal areas. Urban drift was identified as one major potential negative effect of further reductions in reef fisheries: further declines in landings were expected under the status quo. A need for urgent and comprehensive action was clear to most participants. Concerns were expressed about several government development initiatives going ahead in a way that is not being linked to the sustainability of the underlying resource. One example is the introduction of ice plants into remote areas to increase sales opportunities (chilled fish can be stored to wait for bulk shipments to markets) without reviewing whether the resource base can withstand the resulting increase in fishing pressure. Another is the development of the live reef fish trades (groupers for food and ornamental fish for aquaria, for example) without analysis of the underlying resource base in most areas of Fiji and without clear management plans.

Six major findings and recommendations were identified.

1. Assess the economic and social value of coral reef fisheries to Fiji

An assessment of the full value (i.e. including not only market value but also food and livelihood worth) of coral reef fisheries to Fijian society would better enable appropriate resources to be allocated to this critically important, but largely ignored, sector for management and enforcement.

2. Information and outreach

Participants identified a need for a much better understanding of the importance of balancing resource use with management. This need was clear throughout the discussions and presentations, and assistance in this area was repeatedly requested at many levels, from communities to government officials; education and outreach on existing fisheries regulation were acknowledged to be poor. Participants also recognized that more information is needed on threatened and vulnerable species, such as the humphead wrasse, *Cheilinus undulatus*, bumphead parrotfish, *Bolbometopon muricatum*, giant grouper, *Epinephelus lanceolatus*, and giant sweetlips, *Plectorhinchus obscurus*.

3. Management and enforcement

Enforcement of current fishery regulations for coral reef fisheries was been widely perceived to be weak to non-existent, but very much needed. The

1. Society for the Conservation of Reef Fish Aggregations and University of Hong Kong. Email: yjsadovy@hku.hk
2. Fiji Fisheries Department, Ministry of Fisheries and Forest, PO Box 3165, Lami, Fiji. Email: abatibasaga@fisheries.gov.fj

overriding perception by all sectors was that little is being done in respect of fishery management and controls. Community leaders wanted to know more about how the policies and practices for issuing fishing licences could be improved, and they expressed the need for assistance in management and to address poaching. Marine protected areas were identified as an important management tool, but one that, if used alone, is insufficient to adequately manage the inshore fishery sector.

4. *Match the marine resource base with government development initiatives*

There is currently little attempt to match new development initiatives, such as product development or export fisheries such as live reef food fish or jellyfish, with the capability of the resource base to sustain such development. This shows that the development and management "arms" of the fisheries department are not integrated or coordinated, and that development could even be counter-productive.

5. *Nearshore development/reclamation*

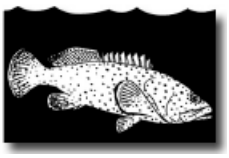
In many areas of Fiji, dumping and coastal developments are destroying coastal areas; based on studies from elsewhere, such activities almost certainly have long-term negative impacts on reef fisheries. Development associated with tourism can sometimes be more of a threat than a blessing, if not carried out with proper planning and consultation.

6. *Integration*

Given the many initiatives already addressing or beginning to address marine coastal issues, a need was recognized for integration and coordination among these initiatives to avoid unnecessary overlap, and to ensure that significant gaps in information are filled.

Participants at the meeting found the presentations to be useful and constructive and requested follow-up meetings at the national and regional levels. A report on the meeting will soon be posted on http://www.scrfa.org. It was recommended that the next meeting be held in Fiji in mid-July, 2007.

Figure 1. Participants at the meeting, "Reef fisheries: Now and for the future", in Suva, July 2006.



News and events
live reef fish

Big gains seen for Vietnam's ornamental fish industry

An 8 February 2006 article in Vietnam News describes the recent growth in Vietnam's ornamental fish industry: http://vietnamnews.vnagency.com.vn/showarticle.php?num=01BUS080206

Hundreds of endangered coral reef fish released in Indonesia

According to a 9 February 2006 news release by WWF, "Hundreds of humphead wrasse were released back into the waters of the Bunaken National Marine Park after being confiscated from a fisherman who was intending to illegally sell the internationally protected fish species abroad."
See http://www.panda.org/news_facts/newsroom/index.cfm?uNewsID=59380

US Coral Reef Task Force to investigate cyanide use

In May 2006, the US Coral Reef Task Force approved a resolution to examine the use of cyanide and other poisons in the collection of reef fish that are traded on the global market. See story at: http://www.noaanews.noaa.gov/stories2006/s2625.htm, and reports from the meeting at: http://www.coralreef.gov/taskforce/meetings/meet8.html

Researchers appeal for new regulations to save coral reefs from live fish trade

According to a 5 August 2006 news release from the University of Cambridge, 20 of the world's leading marine scientists have called for action by governments to halt the unsustainable plunder of the world's ocean resources, and in particular have identified the live reef fish trade as a serious threat to the health of the world's coral reefs. See: http://www.sciencedaily.com/releases/2006/08/060804102541.htm

PNG's Siassi Island looks to reef fish trade

A 16 October 2006 story in the Papua New Guinea Post-Courier describes a local project on Papua New Guinea's Siassi Island aimed at teaching young people to catch and sell live reef fish. See story at http://pidp.eastwestcenter.org/pireport/2006/October/10-18-15.htm

Moving certification forward in the Solomon Islands

Source: *MAC News*, 4th Quarter 2005

The WorldFish Center (WFC) with MAC, World Wide Fund for Nature (WWF) and the Solomon Islands Fisheries Department will undertake a three year New Zealand Agency for International Development (NZAID) supported project on capacity building. The goal of this project is to achieve a responsible marine

aquarium trade that supports sustainable livelihoods and poverty reduction in parts of the Solomon Islands. The MAC related aspects of the project will include:

- training in the Collection Area Management Plan (CAMP) development and compliance with the MAC Ecosystem and Fisheries Management Standard (EFM) for fish collectors and community stakeholders in areas where fish are collected;
- training in fish collection methods, post-harvest handling, packing and other aspects of compliance with the MAC Collection, Fishing and Handling Standard (CFH), for those engaged in collection of specimens from the wild;
- providing advice on methods used by participants involved in aquaculture for marine ornamentals that will be in compliance with the Mariculture and Aquaculture Management Standard (MAM); and
- training in the process to achieve compliance with the MAC Holding, Husbandry and Transport Standard (HHT) for exporters based in Honiara.

The project will enable collectors of marine species for the aquarium trade, aquaculturists and exporters involved in the project to apply to be assessed for compliance with the relevant MAC Standards.

Certification follow up in Fiji

Source: *MAC News*, 4th Quarter 2005

Post-certification work continues with the two MAC Certified exporters to follow up on the use of the MAC Label and chain of custody issues. The exporters' main challenge relies on their compliance with existing aquarium trade policies and guidelines set by the Fijian government, in particular the ones in relation to CITES. This includes resource-based quotas for live coral and live rock species.

Test certifications underway against MAC MAM Standard

Source: *MAC News*, 4th Quarter 2005

Test certifications against the MAC Mariculture and Aquaculture Management Standard (MAM) in Hawaii and the UK are to take place around this end of 2005. The results of this work will be reviewed by the MAC Standards and Certification Advisory Committee (MACSCAC) in early 2006. Following this review by the MACSCAC, the MAM Standard will be released for public comment, prior to be finally published in the first quarter of 2006.

In addition to the complete MAC MAM Standard there is also a version enabling those facilities which already hold the MAC HHT Certification to include their "in house" culturing of marine ornamentals to their existing scope of Certification.

For further information, or if you wish to be sent a copy of the MAM Standard when it is issued for public comment, please contact Peter Scott, MAC Certification System Director at peter.scott@aquariumcouncil.org.

The first MAC certified cultured marine ornamentals now available, including the world's first MAC certified cultured live rock

Source: *MAC News*, 1st Quarter 2006

The MAC Mariculture and Aquaculture Management (MAM) international Standard has been finalized for its initial use. Three producers have already successfully achieved MAC Certification.

The MAM Standard covers the mariculture and aquaculture management, propagation, collection, and culturing of marine aquarium organisms, including:

- facility set up and operation, such as of sea cages, cultured live rock, coral propagation, growout ponds;
- culturing activities, from broodstock/post-larvae collection through to grow-out for market; and
- packaging and transport of cultured marine ornamentals.

The Standard includes culturing in the natural environment as well as in "stand-alone" operations (i.e. operations solely for culturing of marine ornamentals) and "in facility" operations (i.e. culturing and propagation in facilities for wholesale, retail, research, etc).

In January, two independent MAC Accredited certifiers undertook a test Certification audit and evaluation of compliance to the MAM Standard of three companies, one in the UK and two in the US, which have successfully obtained MAC Certification.

These cultured fish and live rock respond to the increasing demand for MAC Certified organisms by offering a complementary supply to the existing wild caught MAC Certified marine ornamentals. To be sold as MAC Certified, these marine ornamentals have to pass along the unbroken MAC Certified chain of custody, guaranteeing their traceability and their optimum health.

The newly MAC Certified companies that are providing the world's first internationally MAC Certified cultured marine ornamentals, including live rock, are:

- Hawaiian Live Rock, Hawaii;
- Rain Garden Ornamentals, Hawaii; and
- Tropical Marine Centre, UK.

The contact information for these companies is to be found on the MAC website, where the only official list of MAC Certified operators is available at: http://www.aquariumcouncil.org.

The tested final draft of the MAM international Standard is now available for other companies seeking Certification under the pilot phase of its implementation in 2006.

If you are interested in becoming MAC Certified under the MAC MAM Standard for the pilot phase, then please email: info@aquariumcouncil.org.

First ever documentation of "roving" collection practices

Source: *MAC News*, 2nd Quarter 2006

In Indonesia, aquarium fish collectors rove for a variety of reasons, but it is fair to say that roughly 10–15% of all fishers (not just aquarium collectors) are mobile, following their seasonal prey wherever there is abundance. This practice is allowed by the Indonesian government. The country has an "open-access" policy on marine resources.

Fishing is traditionally, and inherently, a "roving" industry to begin with where fishermen follow schools of fish. The marine ornamental industry is generally more than an exception to this, where resources tend to be static around coral reefs. Collectors rove to enable them to fish in the most abundant areas where the highest value fish live. However, this common practice can lead to overfishing and reef destruction of the collection areas.

MAC has started to study the roving collection situation as part of the efforts to involve the full range of fishing activities into the transformation of the marine ornamental trade. Interviews with collectors and exporters have been taking place since 2005 and, according to the local industry operators, about 80% of all fish collected come from roving fishers. This represents a significant figure, both in terms of volume and value of the catch. Moreover, the roving collectors provide a larger range of caught species available to the market.

In order to have a better documentation of the situation, the first MAC trip with roving collectors was organized last April. MAC representative, Sudaryanto, joined a group of 19 roving collectors as they traveled from Bali to South Sulawesi. Covering a distance of over one thousand, six hundred and seventy (1670) kilometers, this long journey started from Sumber Kima village in North Bali to reach the collection areas on the Karumpa reefs. These fringing reefs extend to several kilometers to the northwest of the Karumpa Islands, southeast of Taka Bonerate National Park, and are acknowledged by fishermen as an ideal area for fish collection.

During the 13 days of traveling, collectors consciously prepared their fishing gears. They use three different kinds of nets with different sizes of mesh: the fine mesh netting is made from mosquito nets; medium nets use a mesh of one-fourth of an inch and one-half of an inch for large sizes.

Sudaryanto noticed that the group of collectors started to spend six hours a day in the water, as soon as they arrived at the fishing site. The shallow water of the site provided fishermen a safe diving environment. They could collect in the seagrass beds of the inner reefs a majority of the popular common clownfish (*Amphiprion ocellaris*) and other clownfish species. After six days of collection, fishermen caught over 14,253 fish representing 65 species.

This successful collection trip, as with the previous ones, has encouraged the roving collectors of Sumber Kima to travel twice a month to the Karumpa reef site, over many years. This practice is well known in Indonesia, and has led local authorities to provide collection permission to roving collectors prior to their journey. However, they sometimes need to move on to find new collection areas if they are no longer allowed to collect in a particular site.

This journey provided MAC with a better understanding of the roving collection practice. The collected data and the experience itself will encourage MAC to continue working with those communities to enhance a sustainable management of the reefs using best practices.

Solomon Islands livelihood programme

Source: *MAC News*, 2nd Quarter 2006

The World Fish Centre (WFC) project "Creating Rural Livelihoods in the Solomon Islands Using Environmentally Friendly Aquaculture and Trade of Marine Ornamentals" is well underway. MAC involvement is ramping up with its participation in the Post-Larval Workshop held at the project site in Gizo, Western Province, Solomon Islands. At the workshop, there were 26 participants from 8 communities around Gizo Island, with among them 6 women. They were taught post-larval fish and invertebrate collection and culture techniques in addition to the MAC best practice techniques for collection, handling and transport. MAC provided major input to the practical sessions when the best-practice techniques were demonstrated.

MAC and its project partners (WWF [World Wide Fund for Nature] and WFC) will continue providing technical support to communities to ensure that farmers are adequately trained in the second year of this program, starting in July 2006. The next step for MAC will be to introduce the concept of the Collection Area Management Plan (CAMP) and the Mariculture Area Management Plan and train communities to develop and implement these plans.

Director's Note

Source: *MAC News*, 3rd Quarter 2006

How many marine aquarium fish collectors will die before the marine aquarium trade becomes safe and sustainable?

In September another fish collector in Bali was killed while working to support his family with the meager earnings from his difficult and dangerous work.

In this case, Bacok and a fellow collector were diving near their village at depths of 30–40 m to collect yellowlined anthias (*Pseudanthias luzonensis*), squarespot anthias (*Pseudanthias pleurotaenia*) and two color dottyback (*Pseudochromis paccagnellae*). As is usually the case in Indonesia and many other poor countries, the collectors had no dive watches or depth gauges. Rough weather caused the anchor to drag. A big wave caught the drifting boat and the divers were yanked abruptly to the surface by the air hoses attached to the tire compressor on board. Bacok was dead when he reached the surface, with burst lungs, leaving behind a wife and two young children. The other collector survived.

Bacok was only one of several collectors who die or are maimed each year while trying to fill their orders.

Most of these deaths and other work-related injuries of collectors go unrecorded. The collectors are poor and may be among the few people in the village with work. Their death or incapacitation generally has catastrophic impacts on the family and friends who depend on their income, as social welfare support systems are limited or non-existent.

Yes, diving is inherently dangerous – but could this accident have been prevented? Bacok was an experienced collector diving at significant depths. What factors oblige these ill-equipped collectors to take such risks?

Unfortunately the relatively low prices paid for most shallow-water species create a strong incentive for collectors to seek out the rarer, more expensive species, many of which inhabit in greater depths. The industry and hobby need to be aware of the risks collectors take to hunt down species that occur at great depths and make more informed choices about the animals they buy. Support from the industry and hobby for adequate equipment and training as the norm for marine aquarium fisheries in all countries would certainly help to make collection practices safer. Improved prices for fish caught under safe conditions would act as an incentive to collect in shallower water – with the added benefit of creating a "depth refuge" for the deeper reef habitat and stocks.

We should all ask ourselves, especially those buying marine ornamentals, whether industry member or hobbyist: What can I do to help prevent this kind of tragedy and help ensure dignity, decent earnings, and safer working conditions for the collectors who make possible my livelihood or hobby?

Over 70 species of MAC Certified fish available in North America

Source: *MAC News*, 3rd Quarter 2006

The variety of MAC Certified fish coming into North America continues to grow, with over 70 species available for retailers as of September 2006. All of the MAC Certified retailers in North America are stocking a good selection of MAC Certified species. In addition to the highly desirable species mentioned in the 2nd Quarter MAC News, other noteworthy MAC Certified fish include majestic angelfish (*Pomacanthus navarchus*), lyretail anthias (*Pseudanthias squamipinnis*), psychedelic mandarinfish (*Synchiropus splendidus*), bicolor foxface (*Siganus uspi*) and exquisite fairy wrasse (*Cirrhilabrus exquisitus*).

North American hobbyists also have the opportunity to acquire MAC Certified cultured species, with cultured false percula clownfish (*Amphiprion ocellaris*) being offered at MAC Certified retailers. Producers of these cultured marine ornamentals became MAC Certified in January 2005 for their facility's compliance with the international Mariculture and Aquaculture Management (MAM) Standard.

Collectors and exporters make digital traceability in the marine aquarium fishery work

Source: *MAC News*, 3rd Quarter 2006

Under the "Identity Preservation and Traceability" project funded by the United States Agency for International Development (USAID) through the Academy for Educational Development (AED), MAC worked with collectors and exporters to undertake pilot scale development and implementation of a prototype integrated, real-time, web-based information technology (IT) system for traceability. This system covers collector to exporter interactions in the Philippines, and facilitates compliance with MAC international Standards, with a focus on electronically documenting and tracking shipments to enhance supplier-buyer relations and improve the Philippines' marine aquarium trade.

In developing this "IT traceability system", MAC worked extensively with marine aquarium ornamentals' MAC Certified collectors groups and their coordinators in seven municipalities in the Provinces of Cebu, Bohol and Palawan and with two MAC Certified exporters. The participating collectors, coordinators and exporters were able to understand and use the system with the hardware (computers, printers, and personal digital assistants), software, and training available through the project. MAC, in association with AED, leveraged a unique public-private partnership to facilitate the design and development of this technology for the marine aquarium trade, which was demonstrated to a multi-stakeholders audience, and

resulted in the acceptance of the technology at the local community level. Among the principal partners is the Microsoft Corporation, which provided a major software grant as part of the project.

By electronically monitoring the movement of marine aquarium fish through the supply chain, traceability and value can be preserved to promote better return for collectors, and improve efficiency, quality and sustainability for a better managed and documented trade.

For marine ornamental collectors and coordinators the traceability IT system presents several advantages:

- eliminating unreliable and burdensome paper-based documentation,
- enabling coordinators to receive quicker feedback on shipment results and payment details,
- calculating the catch per unit effort (CPUE) per species to avoid over-harvesting,
- enhancing business processes, and
- strengthening presentation and marketing efforts in relations with exporters.

This system can also become a very useful tool for exporters, importers and retailers, by:

- allowing automation of their inventory capability and other core business functions,
- informing better potential buyers of stock availability and organizing shipments that require stocks from multiple sources,
- reducing costs, and time needed to collect, track and verify the data,
- streamlining the overall business processes, and
- encouraging a "collect to order" process and ethos that will reduce pressure on stocks.

While this demonstration project of the prototype IT traceability system and accompanying equipment have been readily accepted by users, there remain many challenges to promoting digital inclusion in the marine aquarium fishery. At the level of coordinators and communities, there is a need for solid IT and communications infrastructure, reliable electricity, access to supply inputs (and related financing), and computer skills upgrading. Moreover, the system will need to be extended to importers and retailers so that "end to end" transactional capability is established. MAC is working to develop project possibilities to continue this work that can improve the efficiency, quality and sustainability of the marine aquarium trade.

"South-South" capacity building: Indonesia collectors learn responsible collecting techniques from skilled Philippines' fisherman

Source: *MAC News*, 3rd Quarter 2006

Marine ornamental harvesting in Pulau Seribu, Indonesia started around 1960, with the majority of collectors coming from Panggang Island. Many collectors still only use masks, without snorkels or fins. Around 1970, cyanide was unfortunately introduced to the area by others in the marine aquarium industry.

As a result of recently increased enforcement of laws prohibiting cyanide use, and the rapidly rising price of cyanide, collectors and suppliers have committed to alternative techniques for collecting fish. In July 2004, a marine ornamental collectors' group PERNITAS (Perhimpunan Nelayan Ikan Hias dan Karang Hias), was formed in Pulau Panggang. MAC trainers and TERANGI (Indonesia Coral Reef Foundation), a local reef conservation and management organization, have trained the collectors in best practices for collecting and handling to ensure that the fishery is sustainable. However, more specialized training was needed for responsible collecting of some species.

In August 2006, the PERNITAS collectors group received training from Regenito Gador, a Filipino trainer, on techniques for collecting difficult species, such as the green Mandarin (*Synchiropus splendidus*) and comet or marine betta (*Calloplesiops altivelis*). The collectors were taught how to make collecting equipment, such as push nets and traps and were shown better post-harvest handling and holding techniques. Regenito was accompanied by Made Partiana: an Indonesian trainer from Les Village in Bali, who also learned the collecting techniques. After the Pulau Seribu efforts, both trainers travelled to Bali, where they trained collectors from Sumber Kima and Pejarakan in the use of the responsible methods. This peer-to-peer training by Made Partiana will continue in other Indonesia villages, where more collectors are interested in learning these techniques.

Marine finfish: Economics and marketing analysis of the live reef fish food trade in the Asia-Pacific

Source: *Asia-Pacific Marine Finfish Aquaculture e-News*, No. 31 (26 June 2006)

The second workshop of the ACIAR project: Economics and Marketing Analysis of the Live Reef Fish Food Trade in the Asia-Pacific Region was held at the Gurney Hotel, Penang, Malaysia, on 14–16 March 2006.

This ACIAR project is led by the Australian National University, leaded by Dr Brian Johnston, and managed by Dr Ray Trewin. Collaborating Institutions include, University of Western Australia, James Cook University, WorldFish Center, Secretariat of the Pacific Community, Bogor Agricultural University, and Center Research Institute for Marine and Fisheries Product Processing and Social Economics.

The project was to understand the economic drivers and issues of supply and demand of the live reef fish food trade (LRFFT) in the Asia-Pacific, to help shape future industry development and inform social and environmental issues. Possible policy options for a sustainable development of this sector are also included.

The second workshop consisted of series of presentations by the researches on LRFFT to quantify the short and long term demand, supply, and to measure the key cost and risk components in the marketing chain.

Presentations:
- Demand for various types of fish in Asia (Dr Madan Dey)
- Asian fish model: Outline of structure and approach (Dr Madan Dey)
- Development of the LRFFT sub-model (Dr Roehl Briones)
- Projections on supply, demand, and trade for the live reef fish food market in East and South-east Asia (Dr Roehl Briones)
- Indonesia LRFFT (Dr Sonny Koeshendrajana)
- Indonesian live reef fish modeling (Dr Akhmad Fauzi)
- Trade and management in the Pacific (Dr Being Yeeting)
- Developments in culture fisheries (Dr Mike Rimmer)
- Market chain analysis (Mr Geoffrey Muldoon and Mr Bill Johnston)
- NACA role and contribution (Mr Koji Yamamoto)
- Wholesale and retail demand in HK (Dr Liz Petersen)
- ReefBase: Coral reef fisheries portal (Mr Marco Noordeloos)
- Wholesale and retail price integration in HK (Dr Liz Petersen)
- Market price integration by species and country of origin (Dr Liz Petersen)
- Integration supply and demand analysis for the study of policy options for improved market performance (Dr Liz Petersen and Dr Roehl Briones)
- Survey and taste test in HK (Ms Noel Chan)

The papers presented at this workshop will be summarised into a book of proceedings.

The proceedings of the first workshop (held at SPC in Noumea, New Caledonia in March 2005) are available on the ACIAR website (http://www.aciar.gov.au/web.nsf/doc/ACIA-6MP3SJ).

Proposed legislative amendment in Hong Kong: Should live fish be regarded as food?

Source: *Asia-Pacific Marine Finfish Aquaculture e-News*, No. 33 (31 October 2006)

A report released 27th September 2006 by the local think-tank Civic Exchange calls for legislative change to protect consumers from toxins in live fish sold as food. Over 600 cases of ciguatera fish poisoning — caused by eating subtropical or tropical fish that have fed on toxic algae — have been reported in Hong Kong since 2000. Live fish is not regarded as food under existing legislation and the report outlines three recommendations to address the concern:

i) Legislative amendment. The Hong Kong Special Administrative Region Government needs to review and amend the existing regulatory mechanism on imported aquatic products (particularly the signifi-

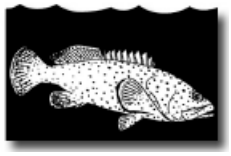
cant volumes of live food fish) so that live fish is properly regarded as "food" for human consumption, thereby ensuring food safety in live fish consumption for the people of Hong Kong.

ii) Ciguatera fish poisoning. Ciguatera fish poisoning is a threat not only to the health of the general public but also the local seafood related industry and tourism. The government needs to take effective action to prevent the public from being exposed to ciguatoxins from imported live reef food fish.

iii) Centralized live seafood market. In parallel with regulating the import of aquatic products (including live food fish) through legislation in terms of food safety issues (e.g. outbreaks of ciguatera, shellfish poisoning, cholera, etc), the government should set up a centralized market for all live seafood commodities so that food testing, origin tracing and the quarantine of all imported aquatic products (live) can be conducted in one place.

A copy of the full report can be downloaded at: http://www.civic-exchange.org. Please feel free to contact Mr Thierry T.C. Chan for further discussion and exchange of views.

Thierry T.C. Chan
Researcher, Civic Exchange
Address: Room 701, Hoseinee House, 69 Wyndham Street, Central, HK.
Tel: 92014737
Email: thierrychan@civic-exchange.org
Website: http://www.civic-exchange.org



Noteworthy publications
live reef fish

Johnston B. and Yeeting B. (eds). 2006. Economics and marketing of the live reef fish trade in Asia-Pacific: Proceedings of a workshop, 2–4 March 2005, Noumea, New Caledonia, hosted by the Secretariat of the Pacific Community. ACIAR working paper No. 60. Canberra: Australian Centre for International Agricultural Research. 163 p. [http://www.aciar.gov.au/web.nsf/doc/ACIA-6MP3SJ]

Contents:

- Workshop Overview (Brian Johnston and Being Yeeting)
- The live reef food fish trade in Fiji (Ledua Ovasisi)
- Review of the live reef food fish fishery operation and its management in Papua New Guinea (Leban Gisawara)
- The live reef food fish and ornamental fish trades in Kiribati (R.T. Awira)
- Summary of important events in the development of the live reef food fish trade in the Solomon Islands (Peter Rex Lausu'u)
- A socioeconomic perspective on live reef fish for food trade for small-scale artisanal fishers based on case studies from the Pacific (Mecki Kronen, Samisoni Sauni, Lilian F. Sauni and Aliti Vunisea)
- SPC's policy on data sharing issues (Being Yeeting)
- Strengthening management arrangements for the live reef food fish trade in the Pacific (Being Yeeting)
- The Indonesian live reef fish industry: Status, problems and possible future direction (Sonny Koeshendrajana and Tjahjo Tri Hartono)
- A predictive dynamic model of Indonesian live reef fish for food (Akhmad Fauzi)
- Finding Nemo: Estimating import demand for live reef food fish (E. Petersen)
- Aquaculture of groupers in Asia and the Pacific (Michael A. Rimmer, Michael J. Phillips and Sih-Yang Sim)
- Market chain analysis for the trade in live reef food fish (Geoffrey Muldoon)
- Development of a spreadsheet model of the market chain for the live reef food fish trade (Geoffrey Muldoon and William Johnston)

Mous P.J., Sadovy Y., Halim A. and Pet J.S. 2006. Capture for culture: Artificial shelters for grouper collection in SE Asia. Fish and Fisheries 7:58–72.

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Pro S. 2006. Cyanide and its unfortunate use in the marine ornamental industry. Reefkeeping 4(12). Retrieved from Web 23 November 2006, http://reefkeeping.com/issues/2006-01/sp/index.php.

Secretariat of the Pacific Community, Marine Resources Division, Information Section
BP D5, 98848 Noumea Cedex, New Caledonia
Telephone: +687 262000; Fax: +687 263818; cfpinfo@spc.int; http://www.spc.int/coastfish