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LIVE REEF FISH

The live reef fish export and aquarium trade

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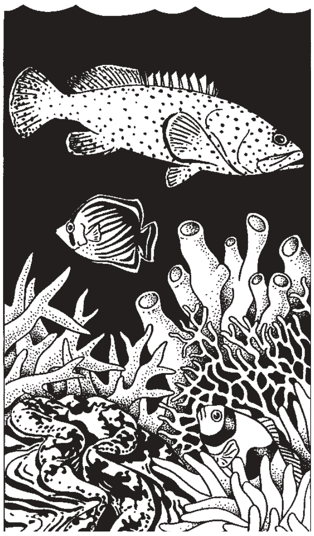
INFORMATION BULLETIN



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Note from the SPC Marine Resources Division

Those of you who are regular readers of this Bulletin, or participate in the LRF Special Interest Group, will be very aware that Bob Johannes passed away in September 2002. We are deeply saddened by his passing, and the tributes from ourselves, and many others, can be found in the already-published Special Edition of the *Traditional Marine Resource Management and Knowledge Information Bulletin* (http://www.spc.int/coastfish/News/Trad/trad.htm).

Bob has compiled, edited and driven the LRF Bulletin since its first issue in March 1996, and has played a vital role in helping SPC to put into practice the recommendation of the 1995 SPC Inshore Fisheries Management Workshop: "A special interest group and newsletter on live fish export fisheries (including both fish for food and organisms for aquaria) be set up under the SPC Fisheries Information Project" (http://www.spc.int/coastfish/Reports/ICFMAP/IFMW2.pdf). We are indebted to him for carrying the guiding light for so long.

However, Bob didn't want the pace to slacken, and had already talked to us about handing over the baton to a new editor although, at the time, we thought it was to enable him to give more attention to another issue that was needing his motivating spark. Tom Graham has bravely taken up the task of editing this bulletin, and we hope that you will give him the support he will need in this difficult transitional period, and in particular by giving him your written contributions to the next newsletter.

SPC's policy is to externalise the editorship of its special interest group bulletins as much as possible — it prevents us from becoming too inward-looking — but editorship is often a thankless task and requires a special perseverance and motivation, not to mention time. We are extremely grateful to Tom for stepping

Inside this issue

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into the breach. It continues a Palau linkage that has lasted throughout the history of both the bulletin and the trade itself. Palau was the first Pacific Community island member to be affected by the live reef food fish trade, and Palau was of course the source of material for Bob Johannes' seminal work *Words of the Lagoon*. It was Noah Idechong of Palau who chaired the session in the 1995 SPC meeting that gave birth to the bulletin, and now Tom Graham, who worked with Noah in Palau for several years, will be editing the bulletin.

Following Tom's transitional editorial below we include the "Editor's Mutterings" that Bob had already transmitted to us for the next issue of the bulletin — challenging and thought-provoking as usual.

From the editor

In each of the disciplines and topics that Bob Johannes delved into, he came up with raw, exciting material — original theories, new knowledge or new evidence for ideas that had been resisted, and always, novel investigative approaches and practical solutions. He also had a knack for synthesis, that rare quality of being able to put pieces together into a coherent whole and present the whole in a meaningful perspective.

In the case of the trade for live reef food fish, Bob may not have been the first to realise the size of the trade and its environmental implications, but he was the one who managed to bring it to the world's attention. And in short order he identified those critical aspects of the trade that we as resource managers, researchers, and educators continue to focus our efforts on: among them, that the great esteem for live reef food fish and the size of the market pose both serious threats and possibly lucrative opportunities for producer countries, that the use of cyanide to capture live reef fish threatens to degrade coral reefs on a large scale, and that the fish stocks targeted in the trade — particularly those that form large and regular aggregations — are susceptible to overexploitation at even modest levels of fishing pressure.

There is some collective anxiety in the scientific and conservation communities about having to take on the challenges related to the live reef fish trades without Bob. There is now a fair amount of attention and resources being devoted to this work, and there are plenty of capable, committed people working on the important issues. But Bob had some qualities that will be very difficult to replace.

Who among us has his or her investigative tentacles spread so broadly across so many disciplines, giving us such a broad view of the problem and the ability to consider solutions from so many different angles? Who can so easily gain the respect and attention of so many different stakeholders, including governments, donors, non-governmental organisations, fishing communities, and the public at large? And who has Bob's ability to stimulate us into thinking about and taking on issues that, until he took hold of them, seemed like non-issues?

As I take over from Bob the role of editor of this bulletin, I am humbled to realise that as usual, I am merely following his lead. But I am comforted to know that I am not the only one in such a position, and that in fact, most of the contributors to this bulletin have in some way been encouraged, inspired, provoked, or otherwise led by Bob.

I had my first chance to follow Bob's lead ten years ago, when I was studying customary marine tenure systems. Bob had not only conducted groundbreaking research in that area, but he also helped catalyse a groundswell of actual transformation of legal systems and resource management practices that continues today through much of the Pacific and Asia. He generously assisted and encouraged my academic efforts. I later had several opportunities to work with him, including assisting him with his research in Palau that was aimed at taking advantage of the aggregating behaviour of groupers for the purpose of monitoring their status. In each of my interactions with Bob I came away richer with the knowledge, ideas and encouragement that he generously shared.

Bob left us with one more of his "Editor's Mutterings," printed below, in which he introduces an article by Craig Thorburn on cyanide fishing in the Kei Islands of Maluku (eastern Indonesia). And he encourages us to consider the role of religious leaders in the live reef fish trade and environmental matters in general.

In this issue, we have two articles on the culture of wild-caught seed. The first, by Patrick Durville et al., describes the results of experiments aimed at assessing the suitability of a number of coral reef species for culturing from the post-larval stage. The second, by Cathy Hair and Peter Doherty, reports on the progress of an investigation in Solomon Islands of the feasibility of developing an artisanal fishery based on the capture and culture of pre-settlement fishes.

Also in this issue, Jill St John gives us a practical review of the pressure-related injurious effects on fish of capturing them at depth. Frazer McGilvray and Thierry Chan provide an update on the live reef food fish trade from the perspective of the market. And on a topic for which we should expect much more news in the future, we have updates on both the continuing initiative to establish a certification system for the marine aquarium fish trade, and a new initiative to establish industry best practice standards for the live food fish trade.

If you received this bulletin by mail, you probably also received a packet of awareness materials related to the live reef food fish trade. Please see the article by Andrew Smith for information about the project that produced them and other materials that are available.

I look forward to receiving your contributions to this bulletin. And please remember that the live reef fish discussion group is available for more rapid communication. You can join it by sending an email to join-live-reef-fish@lyris.spc.int or by visiting www.spc.org.nc/cgi-bin/lyris.pl?enter=live-reef-fish

Tom Graham

Editor's mutterings

Religion and environmental destruction

The propriety of religious leaders is often at least as critical to the health of societies as that of business, political or military leaders. This raises a question for our readers: What are the roles of religious leaders and institutions in protecting the environment in connection with the live reef fish trade? An article by Craig Thorburn in this issue relates the story of a community in the Kei Islands, eastern Indonesia, where villagers captured live reef fish using cyanide to pay for the construction of a new mosque. Indeed, some people in the village disparagingly referred to the project as the "Mosque of Narcotics". Granted, it was not the local Ulama who was exhorting people to poison the reefs; that was the idea of local village leaders and the fish trader. But the Ulama apparently did not speak out against the practice, and it seems unlikely that he was unaware of the malign environmental implications of this scheme.

Spiritual leaders in many western Pacific and Southeast Asian countries sometimes quote from the Bible, Koran or the teachings of Buddha to encourage communities to take good care of God's creatures. But one seldom hears these same voices in debates about actual cases of harmful or destructive practices. For instance, the Catholic Church plays a very large role in the lives of many Filipinos. One wonders why we hear so little about efforts by the Church to discourage the destructive fishing practices that are so rife in that country.

Religious leaders in some western Pacific communities offer their flocks benign environmental leadership, for example in their sermons. Experience in some communities has also shown that when new conservation regulations are announced by the chiefs without ceremony, they are less liable to be obeyed than if they are announced with traditional ceremony and blessed by church leaders (e.g. Johannes l998).

Nearshore fisheries management (among other forms of environmental management) would benefit if environmentally active religious leaders were identified and encouraged, while cases where local religious leaders are either directly involved in supporting harmful enterprises or even just “looking the other way” were brought to light and analysed. In some cases, no doubt, religious leaders have no option but to look the other way given the formidable pressures put on them by some people in the trade, including a dangerous military or police component (e.g. Indonesia).

But in other cases religious leaders may be missing an opportunity to play an important role in the health of their community’s marine resources. Probably there are opportunities for those of us concerned with conservation in this context to help them by providing them with relevant information.

This Bulletin would welcome articles, or even notes, describing religious leadership in the context of the live reef fish trade.

Bob Johannes

Reference cited

Johannes, R.E. 1998. Government-supported, village-based management of marine resources in Vanuatu. Ocean and Coastal Management 40(2–3):165–186.

Correction

In the previous issue of this column I said, “I’ve never seen an article on ethno-aquaculture” — which suggests my reading is very limited indeed. What I meant to say was, “I’ve never seen an article on ethno-veterinary aquaculture.”

Fatal adaptation: Cyanide fishing in the Kei Islands, Southeast Maluku

Craig C.Thorburn[1]

Introduction

Live Reef Fish Information Bulletin No. 4 featured an article by Dedi Adhuri entitled, "Who can challenge them? Lessons learned from attempting to curb cyanide fishing in Maluku, Indonesia". Mr Adhuri completed his research in late 1996; I arrived in the Kei Islands in October 1997 to conduct research on customary coastal resource management practice and institutions.

One of the main reasons that Mr Adhuri and I selected the Kei Islands as our research site was Kei's reputation for robust and highly articulated customary (*adat*) law. Scholars of common property resource management (CPR) and indigenous knowledge systems (IKS) consider the islands of Maluku to be an area particularly rich in customary communal resource management practice and institutions, and within Maluku, Kei stands out as a place where traditional systems and structures have largely withstood the corrosive sociopolitical and market forces that have weakened or peripheralised them in other areas. Perhaps the best known manifestation of Malukan *adat* law is *sasi laut*. *Sasi* is the spatial and temporal prohibitions on harvesting crops, cutting wood, or gathering other products from local gardens, forest, tidal zone, or village-controlled sea, as well as more generalised proscriptions against slander, arguing, fighting, harassing or raping women, and other untoward behaviour. *Laut* means sea – *sasi laut* is rules and restrictions pertaining to marine territories and resources. In addition to its ritual significance of mediating relations between human communities, the natural environment, and spirits of ancestors, *sasi* serves the very practical functions of making sure that nobody takes what does not belong to them, that fruits ripen before picking, that shellfish can reproduce and grow, that migratory or spawning fish are allowed to accumulate and reproduce, and that sufficient food or funds can be gathered for important communal events or activities. In Kei, *sasi* is called *hawear*, and is regulated by several well-known tenets of Kei *adat* law. *Sasi/hawear* changes over time in response to changing markets, technologies, politics, and religion; however, the practice is suffused with a mystique of great antiquity and supernatural force, blending arcane ceremony with modern economy and governance. *Sasi* is generally considered to be in decline in Maluku, although it is experiencing a revival in some places, driven partly by non-governmental organisations (NGOs) and academic interests in customary resource management institutions, the politics of ethnic identity, and attempts to strengthen local communities' traditional territorial claims and resource entitlements (Novaczek et al. 2001; Thorburn 2000a; Zerner 1994).

Dedi Adhuri's article described an incident in a village he called "DL", located on a small island just north of the Southeast Maluku district capital, Tual, in the Kei Islands. Dullah Laut is one of the villages I studied during 12 months in Kei. Many things that Mr Adhuri described still pertained when I arrived, while others had changed significantly. Following is a brief review of Mr Adhuri's article, followed by a description of the changes I encountered.

The "first wave"

Mr Adhuri's article begins with a chronological description of a typical case of local conflict that had arisen due to the arrival of cyanide fishers in Kei. His story is characteristic of experiences in Kei and elsewhere with "first wave" cyanide fishing firms. When I arrived, the live fish industry in the Kei Islands had entered its second phase.

According to Pet-Soede and Erdmann (1998) and others, the live fish trade follows a typical progression. Phase one is the invasion of large cyanide catcher boats, usually owned by well-capitalised and connected firms. These operations take large amounts of fish, causing major damage to local reef ecosystems. Fishing with poisons, and causing harm to the environment are against the law in Indonesia.[2] Bribes and "connections" are commonplace, and local law enforcement agencies are

1. Senior Instructor, Masters in International Development and Environmental Analysis (M.IDEA) program, Monash University. Email: thorburn@attglobal.net. Dr Thorburn conducted field research for his PhD dissertation in Cultural Geography in the Kei Islands for 12 months during 1997 and 1998.
2. National laws and regulations that forbid damaging coral reefs or using poisonous substances include Law Number 4 of Law Number 4/1982 Basic Provisions for the Management of the Living Environment (subsequently replaced by Law Number 23 of 1997), Law Number 9 of 1985 on Fisheries, and the Decree of the Director General of Fisheries Number IK/220/D4.744/91K on Capturing Fish with Forbidden Substances/Equipment.

largely powerless to prosecute violators (or, are actively involved in the illegal activities themselves). If local community members object, they can be subjected to threats and intimidation, given cash payments, or some combination of the two. The latter is more or less in keeping with local *adat* law, where a fine (called *bukman* in the Kei language) is paid to redress damage and appease the offended party.[3]

As fish stocks begin to dwindle, and the companies begin to experience declining returns on capital, they move on to new untapped areas, in the manner of pioneer slash-and-burn agriculturists in newly opened tropical forest areas. As they leave an area, small- and medium-scale operators take over, employing a combination of traps, hook-and-line, and cyanide to catch the remaining fish. These second wave operations usually work in conjunction with local fishers and communities, rather than competing with them. Fish are collected in holding pens, then sold to transport ships that call regularly. These small- to medium-scale enterprises have lower overhead and operating costs, and are happy to carry on with lower volumes and profits than the big first wave companies. By going after smaller fish, and in areas with lower concentrations of fish, these second phase cyanide fishers continue to spread the devastation initiated by the first wave of cyanide fishing.

Adhuri's story begins in August 1996, when two fishermen from Dullah Laut apprehended two cyanide fishing craft and four fishermen. This was easily done, because each of the boats had a diver underwater using a hookah compressor. They could not flee until the divers were safely on board. On each boat, the villagers discovered cyanide tablets, squirt bottles, needles to puncture distended air bladders, and a few live fish in holding tanks. The men worked for a notorious cyanide fishing company called PT Mina Sinega, a joint venture between a Sulawesi-based private fishing firm and the Indonesian Army Co-operative Centre, PUSKOPAD.

When informed of the event, the village head was livid, and struck the offenders. He then secured the confiscated boats and equipment, and delivered the fishermen to the district police headquarters (*Polres*) in Tual. His intention was to quickly consign the case to local law enforcement before the military could intervene and settle the matter with a hasty cash payment. Dullah Laut already had a history of confrontation with cyanide fishing boats, which they felt were encroaching on the village's marine territory. According to Kei custom, every village possesses a marine *petuanan* with locally acknowledged boundaries and rules. Outsiders must request permission to fish commercially in *petuanan* waters, a process that involves deliberation with village elders, ceremonial exchanges, and, if agreed, some form of rent payment. Although such customary marine territories are not recognised by Indonesian fisheries law, the local fisheries service (*Dinas*) in Southeast Maluku, as in many other parts of the country, encourages outside fishing companies to comply with local custom and make separate arrangements with village leaders. Mina Sinega and other cyanide fishing operators had made no such concessions. There had been numerous clashes between local fishermen and these encroachers over the past two years, to the point that Mina Sinega often posted armed soldiers on their boats. A number of cash settlements to secure the release of commandeered boats and crews had failed to persuade Mina Sinega and other cyanide fishers to stay clear of Dullah Laut's marine *petuanan*. The islands north of the Tual harbor featured some of the largest and richest coral reefs in the Kei Islands (Sutarna 1991).

The Police Intelligence Unit Commander agreed to hold the men for questioning, but explained that such cases were very difficult to prosecute, due to technicalities regarding chain of custody and processing of evidence, plus a lack of clear proof that the fishermen's actions had directly damaged the environment.[4] The commander suggested that the matter would best be solved by means of customary *adat* law, which would place the village head in charge. His argument was based on the premise that according to Indonesia's 1979 Village Government Law, the village head is the highest authority within the autonomous village administration. It was an odd case of "political hot potato," with the district police and village head each trying to get the other to handle the case, and thus avoid having to deal with higher level government and military officials.

Still determined to prosecute the case to the fullest extent of the law, the Village Head went next to the head of the district government (*Bupati*) in Tual. The *Bupati* explained quite frankly that, since this case involved an army officer, there was nothing he could do, since the military is not under his author-

3. A typical bukman payment in Kei consists of a small amount of tobacco and betel nut, or, for more serious offenses, a bronze cannon or gong. Lately, bukman more commonly take the form of cash payments.
4. For a discussion of corruption and enforcement of laws prohibiting destructive fishing practices in Indonesia, see Erdmann 2001.

ity. The head of the district fisheries service (*Dinas*) offered the same excuse.[5]

Frustrated by the lack of support from government officials, the village head eventually sought to handle the case according to *adat* law. He presided over a special meeting of the village *adat* council attended by elders of all original kin groups in the village, the Tual sub-district army post commander (*Dandim*), and the fishing company representative. One member of the council suggested a fine of 10 million rupiah (about USD 4400 at that time), reasoning that this was the amount prescribed by national fisheries law. A few individuals, perhaps attempting to curry favour with the fishing company and military, argued for a lower fine, on the grounds the village head had beaten the fishermen.[6] The council eventually settled on a payment of six million rupiah. The company representative said he would need to discuss this with his superiors in Ujung Pandang[7], and would return soon with a response.

The company agreed to pay the six million rupiah fine. When it came time to pay, however, the military commander first took one million rupiah to distribute among his associates as a fee for brokering the agreement. The village head kept another two million, reasoning that he was entitled to a *bukman* for his role in instituting the customary court proceedings. When the *adat* council reconvened, they were told that the company had agreed to pay only three million rupiah, which was then divided into two, half each for the village church and mosque. In accordance with local custom, the company representative then gave an additional 10,000 rupiah "table cloth money" to each of the council members. The case was closed, and the village head returned the boats and equipment to the company representative.[8]

The "second wave"

Not long after the events described above, one by one the large cyanide fishing companies began leaving the Kei Islands. PT Mina Sinega was the first to disappear, falling into bankruptcy through a combination of mismanagement and larceny. In January 1997, the last major company, PT Surya Sulawesi, a joint venture between a retired Hong Kong police inspector and a Ujung Pandang businessman, quietly left without even informing its local agent of its plans. When questioned about the companies' abrupt departure, both the district police commander and regional navy commander admitted that law enforcement obviously had little to do with it, and suggested that "people's power" was the main reason these companies had decided to move elsewhere. Tenacious local fishermen, they felt, had finally hounded the companies out of Kei's waters. Some local fishermen, particularly those organised by local NGOs, agreed with this interpretation. District fisheries service officials also expressed consternation, noting that none of the companies' licenses had expired or been revoked. They suggested that it had become too expensive to operate in Kei, since villagers and local partners were demanding ever more exorbitant fees and fines from the companies.

While these may have been contributing factors, the main reason these companies left was declining yields. They simply chose to move elsewhere, to exploit more productive virgin reefs. In short, this development was merely part of the natural progression from large capital-intensive operations to smaller low-cost operations that characterises the live reef fish and other fishery industries in overexploited Asian waters (Panayotou 1985).

In mid-1997, all that remained of the first phase companies were a few wooden mother ships left rotting on the shore of Bay of Sorbai, surrounded by clusters of cracked red fibreglass runabouts. Underwater, evidence of the companies' recent presence was more graphic. Visual surveys of reefs surrounding several small islands to the north and west of Kei Kecil revealed the extent of devastation caused by six years of cyanide fishing. Live coral cover at three meters depth in many areas was only about twenty percent; at ten meters it was closer to five percent (I. Amin, R. Gustave and F. Cruz pers. comm., 2 March 1999, Denpasar, Bali).[9] The trochus-producing reefs of the north and east coasts of Kei Besar had fared better, protected by the huge Eastern Monsoon waves that render div-

5. Adhuri's investigation later revealed that the district Fisheries Service had issued a letter of recommendation that the offending company be granted a license to operate in local waters, three days after the cyanide fishers had been apprehended in Dullah Laut.
6. Adhuri found out that the most vociferous opponent of the stiff fine had previously signed an agreement with the *Dandim*, granting permission to construct a base camp for a grouper fishing operation on a nearby island, for which he was given a new outboard motor. As hereditary leader of a founding kin group of Dullah Laut, he argued that he was within his rights to enter into such an agreement.
7. Ujung Pandang is the capital of South Sulawesi and a major center of the Indonesian fishing industry.
8. The summary of Adhuri's case study ends at this point. Events described below transpired after he completed his research in Dullah Laut in 1996.
9. Amin et al. concluded that the coral damage apparent in these areas was most likely entirely due to cyanide use — blast fishing had been a common problem in these areas during the 1970s and 1980s, but this activity had ceased many years before this research was conducted.

ing there impossible for about half the year, as well as by strictly enforced village regulations restricting access — that is, *sasi*. There, the amount of live coral cover was greater and resembled conditions described in a National Institute of Science (LIPI) survey of Kei's coral reefs conducted in the mid-1980s (Sutarna 1991). Already, reefs in some areas west of Kei Kecil were showing signs of regrowth, particularly soft corals.

The live fish industry in Kei had entered its second phase. Local operators, either individuals who had arrived with the first wave companies and stayed on, or local traders who had worked with the first wave companies or entered the business subsequently, now dominated the local live fish trade. Three individuals in particular controlled most of the trade in Kei: Ahau, a Taiwanese national who arrived with PT Mina Sinega and formed a joint venture with the wife of the local army officer who played a central role in settling the Dullah Laut case described above; Karno, a man with a military background who also arrived in Kei with another of the first wave companies, and Stanley H., owner of Toko Empat, an office supply and dry goods store that has been in Tual for generations.[10]

During interviews in 1998, these local operators all strenuously denied using cyanide, claiming that only big companies with strong backing from Jakarta could get away with this sort of illegal practice. Local fishermen told another story. These traders take a very different approach to gaining access to village reef territories and resources. Whereas the first wave of companies wielded their power and impunity to run roughshod over local *adat* rules, and were able to argue as well that Indonesian law recognises no local control of national marine territories, the smaller second phase firms generally seek to accommodate local norms and practices.

The most common approach is to provide credit to local fishermen to purchase outboard motors or build floating fish pens, accepting payment in the form of live fish. At first, the traders accept all fish, but soon begin specifying that they will take only certain kinds. This makes it more difficult for the fishermen to meet the payment schedule, and as good patrons, the traders offer help — in the form of little white cyanide pills. Since these fishermen are operating in their own village-controlled marine *petuanan*, this arrangement is not perceived as violating local *adat* regulations.

This presents local law enforcement officials with a dilemma: do they want to subject impoverished villagers to the stiff fines and long jail sentences stipulated by the law? According to the regional navy commander, clearly not (S. Permanto pers. comm., 6 May 1998, Tual, Kei Islands). If they are serious about confronting this problem, they need to prosecute the businessmen who supply the cyanide. The businessmen, though, can argue that they have a perfectly innocent and legal loan arrangement with the fisherman, and cannot be held responsible for his choice of technologies.

An increasingly common arrangement is for businessmen to enter into a contract with an entire village community — either government or *adat* leaders — for permission to develop a live fish business in local waters. The amounts offered, although paltry compared to the profits to be gained, are quite large by Kei village standards. This is particularly true since the collapse of the rupiah. Like other export commodities, the final sale price of live grouper is calculated in dollars. Ten million rupiah, a common price for permission to set up a base camp and fish in village waters, is presently worth only about USD 1200. Still, this is greater than the 6.5 million rupiah that villages officially received at that time from the central government each year to cover administrative costs and village development projects.[11] Additionally, the companies employ local fishermen, or offer the simple loan arrangements described above. In the midst of Indonesia's economic crisis, this is very favourably received in many village communities.

Dullah Laut revisited

Two years after the *adat* court incident described above, Dullah Laut was still the epicentre of cyanide fishing in Kei. After initially battling the outsiders, several young men from Dullah Laut and neighbouring villages had already ceased fighting and gone to work for first phase companies before their abrupt departure in 1996–1997. These were the first people to sign up with the new local firms when they emerged on the scene.

In mid-1998, there were about 18 floating net pens dotting the reef edge in front of the village. These were mostly owned by two of the three main local traders, although some belonged to individual villagers who had already paid off their loans. The larger operation, Ahau's, had eight employees from outside of Kei living at a base camp on an

10. Ahau, Karno, Stanley H., and Toko Empat are all pseudonyms.
11. The actual figure, by the time it reached the village, was usually only a small portion of this amount. In fiscal year 1998/99, the official subsidy was raised from 6.5 million to 10 million rupiah.

island north of Dullah Laut, plus another 30 to 40 local villagers diving for him. Karno, whose base camp is located across a narrow strait on the island of Dullah,[12] had no permanent employees, but worked with about 50 local divers. The third major local trader, Stanley H., did not have permission from Dullah Laut to operate in the village *petuanan* area, but about 10 divers from the village worked for him in other nearby sites. Practically every pirogue (*sampan*) lining the beach in front of Dullah Laut was equipped with a compressor, a sure sign it was being used for cyanide fishing.

A prominent village elder[13] proudly explained that he had "solved the problem with the fishing companies". The large companies that had caused so much trouble before were gone, and in their place were some new, good companies that had "entered through the front door". They had approached the proper *adat* officials, and asked and received permission to fish in local waters. For this, they had paid a handsome fee. Besides, many villagers were working for these companies now, earning large sums of money.

The religious and political history of Dullah Laut plays an important role in understanding the situation there. Dullah Laut is comprised of two separate hamlets, or *kampung*. The original village is now called Duroa, or Dullah Laut Kristen (Christian Dullah Laut). A kilometre to the south is a second enclave, called Dullah Laut Islam. Just after the turn of the century, the traditional village chief (*Orang Kaya*) of Dullah Laut was converted to Catholicism by Dutch priests. A large group followed him to embrace the new faith. His son, however, was convinced by Islamic teachers from Tayando, an island a few hours sailing to the west, to become a Muslim. He and his group moved a short distance away to form a new *kampung*. This was a fairly common occurrence in Kei, and was done without rancour. Muslim converts moved out of Christian or pagan communities to avoid contact with pigs and dogs. Family ties remained strong between *kampung*, and interfaith marriage was common.

As the original village, Dullah Laut Kristen remained the seat of government, until the implementation of the New Order Government's Law No. 5/1979 on Village Government. By this time, Dullah Laut Islam, like many of the other Islamic *kampung* in Kei, had a larger population than its parent village. Furthermore, it appears that the provincial and regional governments generally favoured Islamic villages in determining where the seat of government for newly consolidated village units (*Desa*) would be placed. Dullah Laut's village government is located in Dullah Laut Islam, a reversal of the proper *adat* hierarchy that acknowledges Dullah Laut Kristen as the community's true hearth and centre.

Adding insult to injury, the *adat* elder of Dullah Laut Islam was rejected as a candidate for village head during the government's screening process. Instead, a man with ties to the local *Raja*[14] and Head of the Southeast Maluku District Government (*Bupati*) was nominated for the job. The *adat* elder mentioned above and many of his supporters refused to acknowledge the legitimacy of the official village government. The village head's act of taking two million rupiah *bukman* from the earlier settlement, a fact widely known in the village, stripped him of the moral authority to lead, they claimed.

These schisms, particularly the cooling ties between the two village communities, were easily exploited by cyanide fishers seeking permission to operate in village waters. They made separate deals with each group, confident that the one did not know what the other was doing. Interviews in the two *kampung* turned up quite dissimilar versions of who arrived first, whom they paid, how much they paid, who "entered through the front door" and who was "unauthorised", and the implications of these arrangements according to local *adat* law. These differences were revealed in conversations with an outsider (the two sides were apparently not talking to each other).

Mesjid al-Bius

With the passage of time, the communities of Dullah Laut were also becoming divided into pro- and anti-cyanide groups. The pro-cyanide clique received a powerful boost in early 1998 through a new arrangement to help pay for construction of a mosque in Dullah Laut Islam. The community had been attempting to construct a new mosque for several years. They first tried to collect 5000 rupiah per household each week to support this effort, but

12. Dullah is one of the three main islands comprising the Keis, the others being Kei Besar (Greater Kei) and Kei Kecil (Lesser Kei). Dullah Laut is one of about 100 smaller islands scattered to the north and west of the three main islands. Only about a half dozen of these smaller islands are inhabited.
13. The same man who sided with the fishing company in the earlier case.
14. The *Raja* of Dullah is one of the most powerful men in Kei. Traditionally one of the leading kingdoms in the islands, for many generations the man holding this post has sought and enjoyed close relations with whichever government was in power. The present *Raja* is head of the GOLKAR (the government party throughout the New Order period) faction in the District People's Representative Council (DPRD II), and benefited handsomely over the years from his close association with New Order leadership.

construction remained stalled due to lack of funds. A few villagers had the idea to request loans from the live fish traders, to be paid off in the form of live fish. The two traders quickly agreed, and provided loans of five million rupiah each to the mosque committee. Construction moved rapidly ahead, to the point that the building was nearly complete when I departed in November 1998. Fishermen from Dullah Laut Islam devoted one day each week to catching fish to repay the loans. It took less than four months to pay off the entire 10 million rupiah, and they had requested new loans to complete the project.

The communal basis and socially laudable goals of this arrangement, along with its profitability and ease, provided the live fish companies a most attractive package to offer other communities. Construction of fine churches and mosques is a common aspiration in Kei and most other Indonesian communities. In the Malukan context, the fish-for-mosque (or fish-for-church) arrangement neatly replaces one of the major functions of the *sasi* institution: raising funds for community projects. As more than one villager pointed out, they would have to impose *sasi* to close the area for at least three years before they could hope to raise that much money. A local detractor, however, suggested publicly that the new mosque will have to be named *Mesjid al-Bius*, the Mosque of Narcotics.[15]

Conclusion: A toxic adaptation

As mentioned above, the practice of *sasi* is a well-known feature of many Malukan societies. The spatial and temporal prohibitions on harvesting crops, cutting wood, or gathering other products from local gardens, forest, tidal zone, or village-controlled sea is more than an institution designed to regulate resource use *per se*, but serves a variety of cultural and social functions, encompassing relations between people, the natural environment, and gods, ancestors, and spirits (von Benda-Beckmann et al. 1995). However, it is *sasi*'s potential as a local community-based resource management and conservation institution that has lately captured the attention of scholars, conservationists, and NGOs (e.g. Kriekhoff 1991; Zerner 1994; Basagio 1995; Nikijuluw 1995; Thorburn 2000a, 2000b; Novaczek et al. 2001). The Kei Islands are known for their strong and resilient *sasi* institutions. This is one of the major reasons that Dedi Adhuri and I, along with numerous other scholars over the years, chose Kei for our research site (e.g. Abrahamz 1991; Adonis et al. 1988; Antariksa 1995; Retraubun 1996).

Local legends speak of forms of *sasi* being practised as early as the 14th century, perhaps longer (Ukru et al. 1993). Historians generally agree that *adat* culture in Maluku reached its zenith in the mid-1600s and has been in decline since then. Cooley (1962) predicted in 1962 that the practice of *sasi* would soon disappear altogether. Forty years later, *sasi* is actually enjoying something of a revival in many areas as communities and NGOs attempt to deploy the venerable institution to help protect local territories and resources from outside exploitation, and to strengthen local claims to access and benefits.

Traditional resource management institutions are subject to constant change and adaptation, in response to the local environment, to internal cultural demands and values, and to external forces. This is true of *sasi* as well. Malukan *sasi* has undergone numerous changes in response to migration and war, boom-bust cycles for local commodities, economic exploitation and political subjugation during the "spice wars" of the 16th to 19th centuries, Christianisation and the spread of Islam, colonial government attempts to undermine the power of local hereditary leaders — including actually banning the practice of *sasi* between 1880 and 1893 — and, most recently, the Indonesian government's policy of standardising village government structures throughout the Republic, using a model that does not take into account local cultural forms and practices. Von Benda-Beckmann et al. (1995) document the evolution of *sasi* in Central Maluku from the use of magic totems to warn away enemies and trespassers to its adaptation during colonial times for territorial control and revenue generation, followed by its co-optation by religious and political leaders and, in some cases, its commercialisation. More recently, *sasi* is being hailed as an "indigenous resource management system" grounded in a deep understanding of local ecosystems and what now has come to be known as "carrying capacity" (Zerner 1994).

The fish-for-mosque deal in Dullah Laut can thus be viewed as the latest in a long series of adaptations of the *sasi* institution to outside stimuli. Although *sasi* has not been practised in Dullah Laut for nearly a generation, the new arrangement incorporates many of its features — locally acknowledged boundaries and access rules, and most importantly, the communal function of "social good." It could be that this is the final adaptation; there will soon be no reef fishery to manage. Diving near Dullah Laut in 1998, an expert from the International Marinelife Alliance predicted that at present rates of destruction, the reefs of Dullah Laut would be devoid of life in four more years

15. *Bius*, meaning narcotic, is a term commonly used in Indonesia to describe potassium cyanide or other fish poisons.

(Cruz pers. comm., 30 August 1998, Dullah Laut, Kei Islands). Interviews with villagers in 2001 indicate that Mr Cruz's dire prediction was off by a year — the reefs were already barren.

Postscript

Five months after I departed from Kei in November 1998, the islands were engulfed in the religious conflagration that had broken out in the provincial capital, Ambon, the previous January. Dullah Laut became a major refuge for Muslim villagers escaping violence in other parts of the islands, at one point hosting more than 3000 refugees. Most fishing operations were halted, as people were afraid to leave the safety of their villages, and trading boats avoided the province altogether.

I was able to briefly return to the Kei Islands in November 2001, three years after I had left. The violence in Kei had lasted only three months, but the devastation was widespread and severe. More than 200 people were killed, thousands of houses and public buildings were destroyed or damaged, and more than 30,000 people — more than a quarter of the entire Kei Islands population — were displaced. In hastily erected refugee encampments, more people died of treatable diseases such as diarrhoea, measles, and malaria.

When I visited, communities throughout Kei were well along in the process of reconciliation and reconstruction. Most of the refugees had left Dullah Laut, and "business as usual" had for the most part resumed. Again, the reef edge in front of the village was lined with floating net pens, and motorised *sampan* equipped with onboard compressors were busy coming and going. They were no longer catching fish in Dullah Laut or other nearby islands; there was nothing left to catch. Most of the fishing was taking place in the waters of small islands far to the west and north. While I was unable to confirm this, local sources speculated that the Dullah Laut fishermen were able to take advantage of the post-conflict situation in the islands: many communities required large amounts of cash to rebuild their burned out villages, and many felt indebted to the people of Dullah Laut for the time they spent there as refugees.

I noted two other important changes during my brief visit in 2001. First, the ongoing conflict in Ambon had forced many of the foreign fishing fleets stationed there to seek new homeports. Many of these were now based in Tual. While these fleets fish for offshore species such as tuna far offshore in the Banda Sea, western Pacific, or the southern part of Indonesia's exclusive economic zone, the presence of these Thai and Korean fleets surely increases the numbers of buyers ready and able to transport live fish to markets in Hong Kong and elsewhere in Southeast Asia.

Second is the impact of decentralisation. In January 2001, Indonesia embarked on a radical program to devolve many responsibilities and tasks of governance to the district (*Kabupaten*) level. This included the subdivision of coastal waters, with *kabupaten* controlling the first four miles from the low tide line, and provinces controlling the zone between four and twelve miles from shore. In combination with the ongoing financial crisis in the country, this radical reformation of government is giving rise to many unanticipated and undesired outcomes in the field of natural resource management (Thorburn 2002). Local governments are scrambling to raise revenues using whatever means available. Many local agencies and officials view the sea as a potential source of cash, using both legitimate and illegal means.

Licenses for the large foreign tuna fleets are still issued from Jakarta. But the local government has greater say over what they do in port and nearby — for example, the purchase of baitfish from local lift net operators. As for illegal cyanide fishing, the patterns of corruption and impunity remain the same, only some of the players perhaps have changed.[16]

There are other outcomes of the new decentralisation law and the communal violence in Kei. Even before the new Law no. 22 on regional government was written, an "*adat* revivalism" movement was gaining momentum in many parts of Indonesia, as NGOs and local communities attempted to retain or regain some control over management of local resources and territories. A number of villages on the east and west coasts of Kei Kecil, northern Kei Besar, and the island of Tanimbar Kei were reviving *sasi* as a means to strengthen their claims to local coastal waters and reefs and keep cyanide fishers out as long ago as 1996–1998. The new regional government law restores the "natural autonomy" of Indonesia's villages, and several villages in Kei have taken this to heart and produced village regu-

16. This bulletin has featured numerous articles and commentaries on the relationship between official corruption and destructive fishing techniques in Indonesia. For an intimate study of the effects of corruption on a local fishing community in Indonesia, please refer to "Who is to blame? Logics of responsibility in the live reef food fish trade in Sulawesi", by Celia Lowe in LRF Information Bulletin No. 10, June 2002. The same issue features another piece by Mark Erdmann on community-based efforts to overcome corruption to protect local reefs entitled "Perspective: The WAR on destructive fishing practices." Mr. Erdmann also wrote a case-based overview article entitled "Who's Minding the Reef? Corruption and enforcement in Indonesia," featured in LRF Information Bulletin No. 8, March 2001.

lations on a variety of matters, including access and gear restrictions in their marine territories, and the practice of *sasi*. Similarly, in the wake of the communal violence of 1999, there has been a concerted effort to revive Kei *adat* traditions, grounded in the belief that the conflict was largely a result of Kei people's departure from the "wisdom of the ancestors." This includes efforts in some villages to reinstate *sasi* regulations and practice.

If they move quickly and decisively, there may still be reefs to manage and protect.

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Progress report on the capture and culture of presettlement fish from Solomon Islands

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Introduction

Interest in alternative ways to catch fish (particularly very young fish) for the marine aquarium trade is growing steadily (see articles by Dufour, Pet-Soede et al. in No. 10 of this bulletin). The WorldFish Center (formerly ICLARM) in Solomon Islands has been investigating the feasibility of a new artisanal fishery based on the capture and culture of presettlement coral reef fishes[3] targeted by the live fish trades. Our major motivation has been to find alternative sustainable livelihoods for impoverished coastal communities in the Pacific and Asian regions (Bell et al. 1999). In short, we are seeking fishing methods that are environmentally friendly and ecologically sustainable based on harvesting reef fish at the optimum time in their life history (see section below on Sustainability). The WorldFish Center project differs from similar projects (e.g. Dufour 2002) in that the technology must be simple and affordable since our major objective is to create a new source of sustainable wealth for coastal communities with limited cash-earning opportunities.

Which fish and when?

Before we could determine if a new fishery based on presettlement fish might be viable, we needed information on the availability of culturable species in our study area and whether there was a seasonal aspect to larval supply. This is the first time that fish settlement patterns have been studied in Solomon Islands. The work, therefore, contributes to the general state of knowledge about the resource and permits comparisons with other regions with a longer history of similar research (e.g. Australia, Caribbean and French Polynesia). Some of the fish collected during this monitoring were used to evaluate the logistics and costs of culturing presettlement fish to a size acceptable to the market.

The idea of using light traps and crest nets to collect early life history stages for aquaculture was discussed at a workshop on sustainable reef fisheries held in Kota Kinabalu, Malaysia, in 1996 (Carleton and Doherty 1999; Dufour 1999). Light traps are submerged devices that attract phototactic presettlement fish from the water column (Doherty 1987). Crest nets are stationary nets fixed on reef tops that intercept potential colonists travelling through shallow water on their way to lagoonal habitats (Dufour and Galzin 1993). We used both methods to monitor larval supply of presettlement coral reef fish[4] around Gizo, Western Province, for 24 lunar months between November 1999 and September 2001. Traps and nets were deployed around the new moon each month, when the greatest numbers of fish were leaving the plankton (Milicich and Doherty 1994).

Light traps yielded 92,693 coral reef fish from more than 200 species, belonging to 50 families. Cardinalfish, damselfish and gobies dominated the catch, collectively comprising 94 per cent of the total catch. Crest netting yielded 147,665 coral reef fish from more than 390 species in 81 families. Wrasses, gobies, cardinalfish and eel *leptocephali* were abundant, but more than 20 families made up 95 per cent of the catch. In addition, 2858 cleaner shrimp (*Stenopus hispidus*) and 262 lobster pueruli (*Panulirus versicolor*) were collected by crest nets.

Very few fish of potential value to the live reef food fish trade (LRFFT) were collected by either technique, so all of our results relate to the supply of ornamental species.[5] Fifteen per cent of the light trap catch (13,786 fish from 36 species) were considered to be of value to the ornamental trade. Almost all of these were damselfish, which unfortunately have low marketability in Solomon Islands (see section below on Economics). Only five per cent of the net catch (7796 fish from 88 species) were ornamental species but more than half of these were of higher value than damselfish. It is likely that the valuable component of the catch from both methods has been underestimated due to the deliberate exclusion of gobies and wrasses. Both taxa were abundant in our catches (especially in nets) and certainly included a number of attractive species. We did not include them as potential

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3. Presettlers are postlarval individuals that are ready to leave the water column and adopt a benthic reef-associated lifestyle.
4. The term "fish" here includes teleosts and selected decapods (shrimp and lobster).
5. Marine ornamental fish are generally small brightly coloured species, or species that may exhibit unusual behaviour. Ideally, they should have non-restrictive diets and be capable of adapting to a captive existence (Pyle 1993).

aquaculture targets, however, since most were very small (difficult to identify) and fragile (at least with the net design used in our study). Through improved capture techniques, we hope to add some of these taxa to our list of culturable species.

There was no evidence of seasonal trends in supply of any abundant species or family. Over the 24 months of monitoring, there were numerous pulses of recruitment for various taxa but no predictable patterns. The single exception was that significantly greater numbers of lobster pueruli were captured between June and September in both years (confirmed by further sampling in 2002).

Pros and cons of the two collection methods

In general, the two methods caught complementary sets of species, although crest nets collected a greater diversity of families and also more taxa of high value (Hair et al. in press). Survival was higher among fish collected by light attraction. For example, 90 per cent of butterflyfish from light traps were alive on collection, compared with 40 per cent in crest nets, and 100 per cent of pufferfish from light traps were alive, compared with 13 per cent in nets. Operational features of the harvest methods must therefore be considered before deciding on the preferred technique for any new fishery.

Light traps were found to have three advantages over crest nets. First, traps allow more flexible deployment (deep, shallow, drifting, anchored), resulting in lower site dependency. Second, they yield lower bycatch because trapping depends upon active responses (positive phototaxis and adequate swimming performance) by captured fish. Third, this size-based selectivity and constant water exchange through the submerged trap lead to good survival rates of the retained catch. Light traps were also found to have three disadvantages relative to crest nets. First, the taxonomic selectivity resulting from phototaxis produces fewer valuable fish for Solomon Islands' ornamental market (see section below on Economics). Second, the electrical components of traps require regular maintenance. Third, traps are relatively expensive due to the need for a regular supply of batteries.

Crest nets have two desirable characteristics. First, the cash and logistic costs of operating are modest. Once deployed, a single person can retrieve the catches — in ideal situations reaching the site by foot or by paddle canoe. Second, nets collect a greater diversity of high-value species. Nets also have two inherent disadvantages relative to traps. First, crest nets require very specific physical settings (aspect, exposure, tidal range) for optimal performance (Doherty and McIlwain 1996), which restricts their use to communities living near these ideal locations. Second, the indiscriminate filtration of water crossing the crest results inevitably in a larger bycatch component and greater mortality among the retained catch.

Based on these assessments, it is clear that crest nets offer the better option for a low-cost artisanal fishery, despite inherent limitations and notwithstanding the availability of cheaper light trap designs (Watson et al. 2002). The greater bycatch in nets is the most serious issue with this technique but we emphasise that our nets were designed for sampling larval supply and, as such, they were rigged with cod-ends intended to retain everything without regard to their condition after capture. We believe that purposeful redesign of the cod-ends could result in devices with much lower impact upon the retained catch.

Grow-out of fish and invertebrates

Fish that survived capture and were perceived to be of value were grown out. Initially, we used concrete raceways with flow-through seawater available at the WorldFish Center at Gizo. This strategy allowed us to observe the behaviour of captive fish, develop appropriate feeding strategies, and track their mortality with reasonable accuracy. In the first two years of our study, we maintained more than 120 species of fish from 29 families in these raceways to assess their suitability for aquaculture and subsequent sale. Fish were fed a variety of cheap feeds such as fish roe and minced bonito. Fish pellets and commercial aquarium flake food were also tested but we have not determined whether the expense of such imported feeds is justified. Live rock was offered for shelter and provided a foraging substrate for a number of species (grazing fish, invertebrates).

During our survey, we communicated regularly with the sole aquarium fish exporter based in Solomon Islands (in Honiara), who provided feedback on the marketability of our product. We became aware that many fish on trade lists from other areas (e.g. Baquero 1999) were of little or no value in Solomon Islands and we directed our efforts towards the most valuable species. In the raceways, damselfish, triggerfish, and surgeonfish were more robust than butterflyfish, angelfish, and boxfish. Invertebrates (cleaner shrimp and lobsters) were among the easiest to culture, however, and represented some of the best value among our catches (see section below on Economics).

Towards the end of 2001, we moved the rearing from shore-based facilities to sea cages in the lagoon, mainly because this is the most likely scenario for an artisanal fishery. In mid-2002, we constructed a floating cage system capable of holding up to 16 pens, each enclosing about 1 cubic metre. Fish in these pens had higher survival rates than fish in the raceway. With this structure, we also succeeded in rearing recalcitrant species that had failed to metamorphose in the raceways (e.g. boxfish and angelfish). The floating pens were unsuitable for our two invertebrate species, but these did well in fixed cages attached to the bottom in shallow water under the sea cage.

Dufour (2002) reported that weaning presettlement fish onto an artificial diet produces several benefits, including faster growth. In keeping with our objective of developing simple and cheap culture methods, we are developing modest feeding regimes that will be adequate to precondition fish to life in aquaria without being excessively difficult or costly for the prospective farmer. Our current practice in the sea cages is twice-daily feeding with the same diets that we used with fish reared in the raceways — that is, feeds made from locally available products such as fish roe and minced bonito. Based on this regime, we found that most species were marketable after just two months of culture.

Reducing mortality associated with the fishery

It is a given that mortality of bycatch and target species must be minimised in any responsible fishery (Sadovy 2002). In this case, where cultured products from a new artisanal fishery would have to compete against the wild product currently taken relatively cheaply and easily from reefs, we believe it is essential for the cultured product to have some market advantage. Some form of good practice certification (e.g. the eco-labelling scheme being established by the Marine Aquarium Council), which could result in a price premium being paid for captured-cultured product, would help to offset costs incurred during the capture and culture process.

In order to achieve this advantageous certification, two sources of mortality will need to be minimised in a fishery based on collection of presettlement fish. We have referred above to the mortality of bycatch, which we suggest can be reduced substantially by better design at the back end of the collecting nets. The second source of mortality concerns that of the target species. Wood (2001) suggests that wild-caught juvenile fish — although popular in the aquarium trade — may be more difficult to maintain than adults due to their specialised diets and low resistance to stress. However, our preliminary results support Dufour's (2002) claim that juvenile fish reared in captivity from their presettlement phase and weaned quickly onto an inert diet, handle stress better than their wild counterparts. Ultimately, we accept the recommendations of others (Wood 2001; Sadovy 2002) that it is important to release species found to be unsuitable for culture, treating them as part of the bycatch.

Is fishing presettlement fish sustainable?

Some aspects of the novel fishery that we propose here seem at first appearance to be antithetical to the best practices of traditional capture fisheries, but the differences must be appreciated between fishing for food and fishing for other values. Food fisheries aim to maximise harvested biomass for obvious reasons. In contrast, the appropriate currency for the ornamental trade, which seeks live fish for display purposes, is simply the number of attractive fish.

Recent studies have revealed two relevant insights into the demography of reef fish. The first insight is that many tropical reef fish, whether large or small, live to substantial ages (Doherty and Fowler 1994; Choat and Axe 1996). Maximum adult size is a poor predictor of longevity so the smaller sizes of species sought by the aquarium trade do not indicate that they are more robust to exploitation. To support this claim, large groupers sought by the LRFFT live for less than 15 years (Ferreira and Russ 1994), compared with 20 years for small damselfish (Doherty and Fowler 1994). The second insight is that the transition by presettlement fish between ocean and reef is a substantial bottleneck in their natural populations (Doherty et al. in press), mainly because of the impact of reef predators upon naïve colonists (Carr and Hixon 1995; Holbrook and Schmitt 2002). Bearing both factors in mind, it is clear that harvest of incoming settlers must be more sustainable than removing the same number of older settled stages from the reef after they have reached the greater sizes preferred by the aquarium trade. Moreover, methods for harvesting presettlement fish have no impact upon the natural habitat for settled fish, whereas the collection of settled fish from the reef often results in damage to the coralline habitat. Further, the removal of tiny individuals with minimal biomass must have less impact upon reef trophodynamics than the removal of the same number of settled fish that have grown to sizes currently targeted by the dive fishery for wild ornamental products.

Despite their efficiency, it is important to realise that crest nets are self-limiting devices due to their specific requirements for efficient operation (Doherty and McIlwain 1996). A desktop study has shown that suitable sites for the deployment of crest nets in Solomon Islands are widespread but not common. In fact, it is quite likely that markets for ornamental species may be served adequately from relatively few sites with the lowest transport costs. While these factors may limit the spread of economic benefits flowing from any new fishery based upon presettlement fish, the corollary is that it will be impossible to deplete natural populations of reef fish in Solomon Islands by using these methods. This contrasts with other examples of aquaculture reliant upon wild seed (milkfish, grouper, eel, etc.), where unrestrained harvests have raised concerns about their sustainability (Sadovy and Vincent 2002; Hair et al. 2002a).

Suggested village model for a presettlement capture-culture fishery

We envision that a modified apparatus, resembling a crest net, can provide valuable income for coastal fishers who have access to the right conditions. Although the methodology has been kept intentionally simple, some training will be required to ensure proper handling of the live product. Unlike other aquaculture ventures, which require continuous inputs of labour and energy, wild harvests of presettlement fish can be flexible, leading to wider acceptance. Fish farmers will have greater choice about where to invest their effort: switching energy between subsistence activities (gardening, food fishing) and cash generation as required by various obligations (e.g. school fees). This flexibility is enhanced by the lack of seasonality in larval settlement patterns (observed in Solomon Islands, and expected elsewhere in the tropical Pacific) and the short grow-out period required for most target species.

Village operations would use small cages (such as fine mesh nets suspended from inflated tyre tubes) in sheltered lagoon areas where fish exposed to natural plankton would not be entirely reliant upon the feed provided by the fish farmers. Under these circumstances, the principal care requirements would be supplementary feeding to enhance growth rates, occasional net changes to control biofouling, attention to stocking densities to reduce competition, and perhaps simple prophylactics (e.g. freshwater baths) to control parasites and / or disease. Fish will remain in the sea until they can be transferred to the next stage in the distribution chain. This flexibility is essential for people living in isolated areas where transport is irregular and unreliable.

After basic training, the proposed techniques should be suitable for adolescents or adults of either sex. We have plans for the production of a manual that will explain all aspects of the fishery in simple English and Solomon Islands Pidgin with "how-to" diagrams.

Economics of the proposed fishery

Our experience has shown that only a small proportion of the species that we have caught and reared so far meet the narrow expectations of the current market in Honiara (see below). Nonetheless, the monetary value of our catches from just two small nets (equivalent to three linear metres of reef crest) near Gizo could have sustained a profitable artisanal fishery. The catch of ornamental species from our two years of sampling[6] was estimated to be worth SBD 27,000[7] based on farmgate prices in Honiara. Crest nets provided more than 80 per cent of the value. Cleaner shrimp alone were worth SBD 17,500 (Hair et al. 2002b). Painted lobster and some novel finfish (e.g. pufferfish, batfish) provided the bulk of the remaining value, which indicates that initially at least, this fishery may complement rather than compete with established sources.

Set-up costs for a fishery based on crest nets should be relatively low, especially after modification of the devices to more closely resemble traditional fish corrals. Based on our average catches and best farmgate prices, we estimate that the capital cost of a typical family operation could be repaid within a few months. More accurate estimates can be provided after the modified fish collection device has been built and tested (sometime in 2003). The relatively short (two-month) turnaround of product should be attractive to potential fish farmers, although it will be difficult for them (at least initially) to compete on economic grounds with the larger-sized product taken from the adult population. We hope that this gap may be closed by market forces responding to a superior and / or more ethical product (certified by eco-labelling). There are indications that this will be the case. Although the fish we have produced are relatively small, we have been offered large-fish prices because fish caught and raised using these methods are less shy in tanks and accept food more readily.

Many species that we were able to rear were found not to be profitable in the unique context of Solomon Islands, which has expensive and limited volume for airfreight. Honiara is very distant from the major markets that consume ornamental reef fish. As a result, abundant but less valuable species are rarely exported (e.g. damselfish). Instead, the local dealer

6. Based on the assumption that all valuable fish recorded had survived, been reared, and sold.
7. Price sensitive to exchange rates with the major markets. For example, the value of our catch was about USD 3600 at current exchange rates, but would have been worth USD 4500 in 2001.

has been particularly interested in novel species that are difficult to obtain by conventional means (e.g. lobster, shrimp and puffers). But even a limited trade such as the one in Solomon Islands can provide useful additional income to communities, especially when few other options are available. Of course, we suspect that culturable species that may not be economically viable in Solomon Islands may be profitable elsewhere in the Asia-Pacific region.

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Aquacultural suitability of post-larval coral reef fish

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Introduction

Previously, aquaculture mainly consisted of the intensive rearing of commercially valuable carnivorous species for the food market. Some high-yield operations have proved harmful for the environment (Kautski et al. 1998) or of doubtful profitability (Naylor et al. 2000). In the future, the focus is likely to shift either to new species, such as herbivores or detritus feeders, which occur lower down the food chain, or to the development of new activities, such as fish production for recreational fishing, natural stock rehabilitation and the breeding of species for laboratories or aquaria. These potential prospects in marine resources are at present underexploited, especially in tropical latitudes. Some small-scale farming activities represent, for the moment, only a small output in terms of tonnage, but they can nevertheless prove highly profitable. This, for example, is the case with ornamental fish production, which can be a significant economic activity (Tauji 1996; Dufour 2002).

Mastery of breeding techniques is not always necessary and some aquacultural operations now use young specimens caught at sea that are then transferred to farms (Deniel 1973; Rimmer 1998). In the Mediterranean, the Italians traditionally harvest juvenile mullet, sea-bream and European seabass in an area stretching from Turkey to Morocco, rearing them in the "valli" of the Adriatic (Barnabé 1991). This is also similar for the milkfish, *Chanos chanos*, as Far Eastern fishers have been acquiring specialised knowledge for more than a century through capturing young specimens, which are then transferred to farming units (Smith 1981). In Japan, juvenile amberjack, *Seriola quinqueradiata*, caught in the open sea under floating seaweed masses, are used for subsequent rearing in cages (Kuronuma and Fukusho 1984). This method is still very widely used to supply production units. This kind of fishing is cheap and easy, but the harvests vary from year to year and one poor season could jeopardise a whole year's output (Lequenne 1984).

Recently, aquacultural experiments have also taken place with coral reef fish caught in their natural environment at the post-larvae stage (Dufour 2002; Durville 2002); that is, at their final stage of larval development, which, for most species, corresponds to the stage when they migrate from the pelagic environment to the reef. These catches have been made possible by the development of new techniques such as the crest net (Dufour 1992; Riclet 1995) and light trap (Milicich 1992; Hendricks et al. 2001). On Reunion Island, many specimens were caught using these techniques during a study on the colonisation of the islands' reef flats by fish post-larvae (Durville et al. 2002). Concurrently with that study, and in order to understand how well these coral reef fish might adapt to the requirements of fish farming at this particular stage

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of their development, a number of species were placed in captivity.

Materials and methods

Choice of species studied in captivity

The choice of species was guided by the results of the catches. Each time it was possible to catch more than 30 specimens of the same species during a given sampling period with the crest net, the fish were placed in the nursery tanks. This lower limit of 30 specimens was considered adequate to obtain statistically valid results and corresponded to the number of fish liable to be caught over the same period and therefore theoretically of the same age. Twelve species representing eight different families were selected in this way (Table 1).

The technical resources used in rearing

The fish caught in this study were post-larval; that is, specimens close to metamorphosis. At this stage of development, they no longer have reserves and feed in their immediate environment; their fins are formed and they swim actively (Leis and Trnski 1989). To rear them, we therefore chose conventional techniques, similar to those used in intensive hatchery rearing. The selected fish were placed in glass tanks with a net volume of 0.2 m^3 (1.2 x 0.4 x 0.5 m). The "load" at the beginning of the experiment, that is, the biomass in fresh weight per unit volume, varied from 2.5 to 1125 g m^{-3}, depending on the species. In order not to exceed a critical threshold, set at 1500 g m^{-3}, the rearing of the bigger specimens was done in rectangular polyester tanks of 2 m^3 net volume (2 x 1 x 1.2 m). The constantly replenished seawater (open circuit) was directly pumped from the surrounding environment at a rate of 5 to 10 renewals per day. A rudimentary filtering system using synthetic foam was installed. The water was constantly agitated by an air supplier and diffuser. Natural light was used and did not exceed 500 lux. The bottoms of the tanks were partly siphoned off daily in order to remove the bulk of the waste. The tanks were emptied and cleaned every 28 days, after removing the fish. The high water renewal rate and the low stocking density in the tanks were designed to create an optimal environment for the fish.

The feed had to meet many requirements, the most important of which were that the size of the pieces should be suitable for the size of the fishes' mouths and that the formula should cover the nutritional needs of the fish. Major research work has been carried out in recent years to develop artificial feeds for small specimens such as juvenile marine fish. Whatever the food, whether natural or artificial, the requirements do not change greatly (Barnabé 1991): the fish need proteins, lipids, occasionally carbohydrates, minerals, vitamins and growth factors (Guillaume et al. 1999). Farmed specimens in this study, at the post-larval stage, were sufficiently developed to accept artificial feeds (Barnabé 1988; Foscarini 1988), but an acclimatisation stage called "weaning" has proved necessary. During this transitional phase of 7 to 10 days, which is not taken into account in the growth data, fresh feeds based on living nauplii of *Artemia salinas* and pieces of shrimp and fresh fish, readily absorbed and high in energy (New 1986), were gradually replaced by an artificial feed in the form of extruded pellets (Biomar brand), specially formulated for young marine fish. Processing by dehydration and pressure at high temperature gives this feed better digestibility and better assimilation. It is composed of proteins (52%), lipids (15%), ash (9%) and fibre (1%), plus vitamins A (20,000 IU kg^{-1}), D3 (2500 IU kg^{-1}) and E (200 mg kg^{-1}), and in most cases covers the fishes' main food requirements. Food was distributed by automatic dispensers on a non-stop basis over eight hours, which improved feeding for the relatively undomesticated species whose feeding behaviour is easily disrupted. Also, the juvenile fish, which have a very low absorption capacity and a

Table 1. Families, species, authors and adult diets (after Vivien 1973) of post-larvae captured from reef flats and studied in rearing tanks. Classification is based on taxonomy.

Family	Species	Author	Adult diet
Monodactylidae	*Monodactylus argenteus*	Linné 1758	Omnivorous
Gerreidae	*Gerres acinaces*	Bleeker 1854	Carnivorous
Pomacentridae	*Stegastes nigricans*	Lacepède 1802	Omnivorous
Pomacentridae	*Chromis viridis*	Cuvier 1830	Carnivorous
Pomacentridae	*Dascyllus aruanus*	Linné 1758	Carnivorous
Pomacentridae	*Chrysiptera glauca*	Cuvier 1830	Omnivorous
Labridae	*Stethojulis albovittata*	Bonnaterre 1788	Carnivorous
Scaridae	*Scarus sordidus*	Forsskål 1775	Herbivorous
Mugilidae	*Valamugil cunnesius*	Valenciennes 1836	Omnivorous
Acanthuridae	*Zebrasoma desjardinii*	Bennet 1835	Herbivorous
Acanthuridae	*Naso unicornis*	Forsskål 1775	Herbivorous
Balistidae	*Rhinecanthus aculeatus*	Linné 1758	Carnivorous

rapid digestion, need constant feeding (Guillaume et al. 1999).

Inspection periods and monitoring of fish development

The development period was seven periods of 28 days, thus a total of 196 days. In intensive aquaculture, this period of approximately six months corresponds to the transition of juvenile fish to the growing phase (Frelin 1994). Every 28 days, the fish were anaesthetised before being counted, weighed and measured. The anaesthetic used was clove oil mixed with seawater at a dilution of 0.05 ml L^{-1} (Durville and Collet 2001). This process considerably reduces the risk of disease induced by stress, injury or accident due to handling (Keene et al. 1998). Certain biological parameters were chosen in order to estimate the survival, growth and resilience of specific coral reef fish species. A number of indices regularly used in fish farming (Guillaume et al. 1999) were calculated, enabling us to discuss the responses of the post-larvae and juveniles placed in captivity.

- The specific survival rate (SR): This is the most important parameter in terms of the study's overall results. For each species, the number of fish was counted every 28 days; from this, the survival of each species for the whole experimental period was monitored by calculating the specific survival rate, that is, the percentage of live individuals compared with the original number of specimens introduced to the farm.

- The daily feed ration (R): In young specimens, this is usually between 1% and 5% of the biomass (Lequenne 1984). In our work, this daily ration, initially set at 3% of the biomass, was rebalanced and adjusted on a daily basis depending on the results of observations. It was reduced by 10% when food was left over in the bottom of the tanks or increased in daily increments of 10% until the fish were fully fed. The daily feed ration was recorded every 28 days. It represents the amount of food ingested daily and is expressed as the weight of the food (dry weight) as a percentage of the biomass (fresh weight) at a given time, t.

- The conversion index (CI): This is the relationship between the weight of dry feed consumed and the fresh weight gained (Barnabé 1988), also referred to as the conversion rate (or food conservation ratio). It was assessed for each species every 28 days. It is widely used in aquaculture for the purpose of optimising the quantity of food given in relation to the growth of the animal.

- Growth observed in captivity: At the beginning of the rearing period (t^0), after weaning, fish were individually weighed and measured in order to obtain their initial weight (fresh ungutted weight, expressed in grams, called here W) and their initial length (standard length, expressed in mm, called here SL). Subsequently, weights and lengths were measured every 28 days. Fish were not fed on the day they were measured.

- The specific growth rate (SGR): This is defined as the daily weight gain of the fish expressed as a percentage of its weight at time t (Priede and Secombes 1988). It was calculated for each species after 196 days of experimentation.

- The length–weight relationship: For the great majority of species, weight development in relation to length follows a theoretical equation of the power type (Pauly 1997) and can be expressed in the form: $W = a \cdot SL^b$. For each species studied, the parameters "a" and "b" were computed over the rearing period, as was the coefficient of determination (R^2) for each curve. The closer this coefficient is to 1, the more the weight change in relation to length follows this theoretical curve.

- The coefficient of variation (CV) of the weights: This was calculated for each species every 28 days. It is expressed as a percentage and represents the variability in the weights of the different fish as compared to the mean. The lower and/or more stable this is in relation to time, the more the studied batch will tend to become homogeneous and the more the species can be considered as capable of acclimatising to the artificial environment.

Results

Survival of the species in captivity

For two species (*Gerres acinaces* and *Stethojulis albovittata*), very low survival rates were recorded during the initial rearing periods and their rearing could not be completed. The observations made on these species are therefore incomplete and probably biased by unsuitable captivity conditions. They will not be taken into account in the remainder of this paper. For the other 10 species, the method used made it possible, after more than six months of rearing, to obtain survival rates varying from 60% (*Scarus sordidus*) to 92% (*Monodactylus argenteus, Stegastes nigricans*) (Table 2). Despite the very small size (6.5 ± 0.7 mm) and probable fragility of *Monodactylus argenteus* post-larvae, this species had one of the best survival rates. In comparison, *Zebrasoma desjardinii*, which had larger, apparently more resistant post-larvae (21.6 ± 2 mm), had a lower survival rate (87% after 196 days). Survival is therefore thought to be more dependent on the species than on the initial size at which the rearing process was started.

The most fragile phases are the initial rearing periods, with survival rates for *Scarus sordidus* and *Chromis viridis* of 78% and 80%, respectively, after only 28 days of rearing. For each species, the survival rate tended to increase and stabilise at between 90% and 100% after about 100 days of captivity. As survival rates increased with age of the fish, one can assume that the acclimatisation to rearing conditions and the resilience of individual specimens are a function of time. It should also be noted that some cases of mortality were observed to be one-off events due to various technical shortcomings (water or air supply) or occurred after an abrupt temperature drop (tropical climate disturbance). Some of these mortalities therefore could have been avoided.

Feeding fish in captivity

The feed ration

The feed ration varied over time and, apart from external factors that may have influenced food intake (temperature, stress, disease, environment), it was directly proportional to the weight of the fish. Table 3 gives the daily feed ration over time for the 10 species studied. It varied from 3.1% to 20% of the biomass at the beginning of growing out (t^0), whereas at the end of the experiment (t^{196}) it had dropped to 1.5% to 5% of the biomass. For all species, the daily food requirements were therefore proportionately higher during the initial juvenile phases and gradually diminished with the growth of the individual.

An analysis of needs according to species shows that the greatest inter-specific variability in the daily feed ration occurred at the beginning of the experimental period, especially in small low-weight species such as *Monodactylus argenteus* and *Scarus sordidus*. This could mean that the quantitative needs, expressed in relation to the biomass, are inversely proportional to the weight of the fish during the juvenile period; in other words a low-weight species would have relatively greater food needs than a larger species.

Conversion index

The conversion index (CI), which represents the amount of food necessary to increase weight by one unit for each rearing period, varied according to species and growth period, from 0.9 to 10

Table 2. **Percentage of fish surviving over a 196-day rearing period and initial number of fish (IN).**

Time (days)	*Monodactylus argenteus* IN = 50	*Gerres acinaces* IN = 50	*Stegastes nigricans* IN = 50	*Chromis viridis* IN = 30	*Dascyllus aruanus* IN = 30	*Chrysiptera glauca* IN = 30	*Stethojulis albovittata* IN = 50	*Scarus sordidus* IN = 50	*Valamugil cunnesius* IN = 50	*Zebrasoma desjardinii* IN = 30	*Naso unicornis* IN = 30	*Rhinecanthus aculeatus* IN = 30
0	100	100	100	100	100	100	100	100	100	100	100	100
28	94	74	100	80	83	100	52	78	100	93	93	97
56	94	27	94 *	77	83	93	8	66	94	87 *	93	90
84	92	14	94	67	83	93	0	62	94	87	93	90
112	92	0	94	67	83	90	0	60	94	87	93	90
140	92	0	94	67	80	87	0	60	94	87	87	87
168	92	0	92	63	80	87	0	60	94	87	87	87
196	92	0	92	63	77	87	0	60	90 *	87	87	87

* Technical failure partly explained the drop in the survival rate.

Table 3. **Daily feed ration: weight of food (dry weight) as a percentage of biomass (fresh weight) at time t.**

Time (days)	*Monodactylus argenteus*	*Stegastes nigricans*	*Chromis viridis*	*Dascyllus aruanus*	*Chrysiptera glauca*	*Scarus sordidus*	*Valamugil cunnesius*	*Zebrasoma desjardinii*	*Naso unicornis*	*Rhinecanthus aculeatus*
0	20.0	3.6	4.2	3.6	5.7	20.0	14.9	6.5	3.1	4.7
28	6.8	5.1	8.1	6.6	4.8	5.0	8.2	4.3	2.3	3.9
56	4.2	6.3	5.7	5.0	4.6	6.8	4.7	3.4	2.1	3.7
84	2.1	4.8	6.1	4.0	3.8	7.9	4.3	2.8	3.0	2.7
112	1.8	4.2	6.3	4.1	4.0	7.2	4.3	2.5	3.2	2.8
140	1.5	4.0	5.6	4.1	3.6	5.0	3.8	2.7	3.7	2.9
168	1.5	3.5	5.4	4.1	2.8	3.6	3.1	2.6	3.5	3.1
196	1.5	3.1	5.0	4.1	3.1	3.1	3.1	2.6	3.4	3.3

Table 4. Conversion indices over time for the 10 species studied and mean conversion indices (mean CI) for the 196-day period.

Time (days)	*Monodactylus argenteus*	*Stegastes nigricans*	*Chromis viridis*	*Dascyllus aruanus*	*Chrysiptera glauca*	*Scarus sordidus*	*Valamugil cunnesius*	*Zebrasoma desjardinii*	*Naso unicornis*	*Rhinecanthus aculeatus*
0	-	-	-	-	-	-	-	-	-	-
28	0.9	3.0	2.0	3.0	2.0	1.3	1.8	1.5	1.1	2.1
56	0.9	2.3	5.0	4.0	2.5	2.5	1.4	1.6	1.4	3.0
84	0.9	2.2	7.0	5.0	2.0	2.5	1.4	2.2	2.1	1.7
112	1.0	3.0	8.0	5.0	5.0	3.6	1.7	2.3	3.1	2.2
140	1.0	3.1	4.5	3.5	2.3	2.5	1.9	2.8	3.4	2.7
168	1.4	2.4	10.0	8.0	2.8	1.7	1.9	2.9	3.9	5.3
196	1.5	2.6	6.5	9.0	4.3	2.0	2.5	3.0	3.9	7.0
Mean CI	1.1	2.7	6.1	5.4	3.0	2.3	1.8	2.3	2.7	3.4

Table 5. Linearised growth functions, showing the evolution of the square root of the mean weights over time for the 10 species studied, with coefficients of determination (R^2).

Species studied	Linearised growth function	Coefficient of determination, R^2
Monodactylus argenteus	Y = 0.60x – 0.57	0.99
Stegastes nigricans	Y = 0.24x + 0.07	0.98
Chromis viridis	Y = 0.09x + 0.24	0.99
Dascyllus aruanus	Y = 0.09x + 0.25	0.98
Chrysiptera glauca	Y = 0.25x + 0.19	0.99
Scarus sordidus	Y = 0.17x – 0.19	0.93
Valamugil cunnesius	Y = 1.01x – 0.99	0.98
Zebrasoma desjardinii	Y = 0.48x + 0.50	0.99
Naso unicornis	Y = 0.93x + 1.94	0.99
Rhinecanthus aculeatus	Y = 0.32x + 0.69	0.98

(Table 4). This index is obviously of greater interest in terms of rearing when its value is small, because it means significant growth with low food input, but it also shows the adaptation of the species to a particular type of food. The more the species can take advantage of the food distributed, the lower the conversion index. The species that demonstrated a good mean conversion index over the 196-day rearing period were *Monodactylus argenteus*, *Valamugil cunnesius* and *Zebrasoma desjardinii*. The first species had a conversion index even lower than 1 during the first rearing period; that is, the weight gain was greater than the food input. This phenomenon has been observed in tilapia, catfish and wolf fish, with conversion indices as low as 0.9 (Barnabé 1991). In addition, as *Monodactylus argenteus* was very small at the beginning of rearing (6.5 ± 0.7 mm at t^0), it is quite possible that this fish could have fed on all the nutritional matter present in the continuously renewed tank water. The species that showed a higher conversion index were *Dascyllus aruanus* and *Chromis viridis*, with means of 5.4 and 6.1, respectively, over 196 days. This could indicate poor adaptation to the rearing conditions.

Growth of fish in captivity

Calculation of growth curves from mean weights

The growth of a fish can be simply defined as weight gain over time. Changes in the mean weights over time for the 10 species studied followed a series of ascending curves generally similar to the power type, with coefficients of determination (R^2) greater than 0.95 (Figure 1). A square-root type conversion enabled us to linearise these data and thus standardise and compare the results (Table 5). The slopes of the straight lines obtained, which represent the rate of growth as compared to the initial weight, were between 0.09 and 1.01. The species with the fastest growth rates were *Valamugil cunnesius*, *Naso unicornis* and *Monodactylus argenteus*. Those with the slowest growth rates were *Dascyllus aruanus* and *Chromis viridis*, which can be taken to confirm the previous results pointing to difficult adaptation on the part of the latter two species.

Specific growth rate

Over a short period such as the one used in the study (196 days of rearing), the increase in biomass

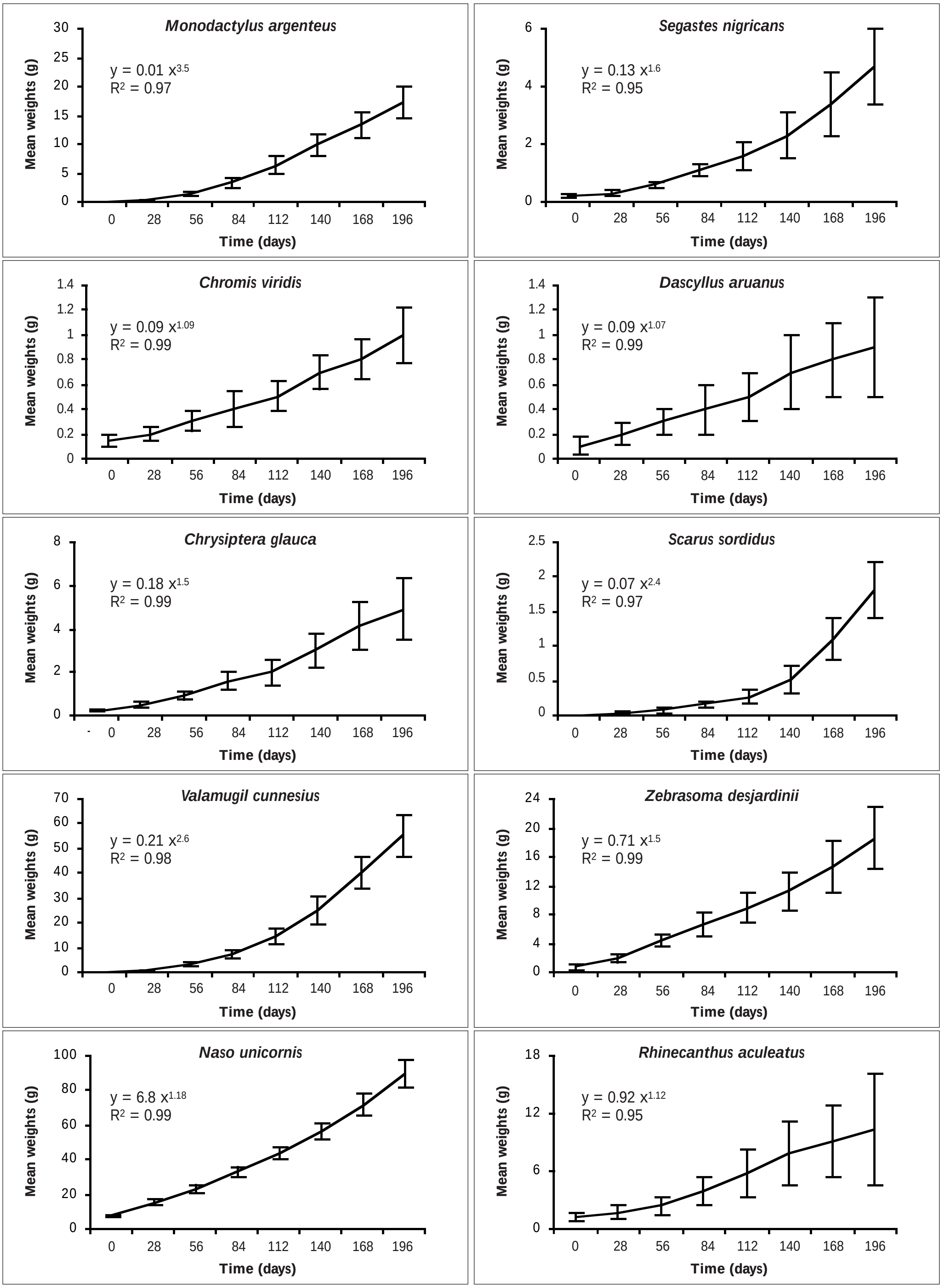

Figure 1. **Evolution of mean weights with time, for the 10 species studied; also shown are the equation of the curve and the coefficient of determination (R^2).**

can be considered as a linear function of time, which enables us to define a specific daily growth rate (Figure 2). The results obtained for the various species ranged from 0.9% to 3.8% daily weight gain. Those with the best specific growth rate were *Monodactylus argenteus* (3.8%), *Valamugil cunnesius* (2.6%) and *Scarus sordidus* (2.6%). *Chromis viridis* had the lowest rate (0.9%).

Length–weight relationships obtained under aquacultural conditions

It is generally acknowledged that the weight (W), of a fusiform fish is proportional to the cube of its length (SL). The equation can be written in the following form: $W = a \cdot SL^b$, in which the parameter "b" is close to 3 (Pauly 1997). It can be verified that this formula is applicable to the majority of species studied, except *Dascyllus aruanus* and *Chromis viridis*, which gave different results (Table 6). The weight of these species could be very low in comparison to their size, which could, as indicated previously, indicate that these fish did not follow a normal development process under the farming conditions.

Resilience of the species studied

Barnabé (1991) uses the term "resilient" to describe the ability of a species to survive and grow in conditions different from those of its natural environment, to tolerate handling (sorting, treatments) and various deteriorations in farming conditions. This capacity can be judged by monitoring the coefficient of variation (CV) of the weights for each rearing period. If the CV diminishes proportionately and / or stabilises, it can be concluded that the animals are adapting appropriately to the farming conditions. This was the case with *Monodactylus argenteus, Valamugil cunnesius, Zebrasoma desjardinii* and *Naso unicornis* (Fig. 3), whose coefficients of variation were stable at about 10% to 20% of the mean after some six months of rearing. With other species, the variation from the mean figures were greater (40% for *Rhinecanthus aculeatus* and 30% for *Chrysiptera glauca*) or showed variations from the mean that were highly variable depending on time, as was the case for *Scarus sordidus*, *Chromis viridis*, *Dascyllus aruanus* and *Stegastes nigricans*. This denotes heterogeneous and discontinuous growth within the

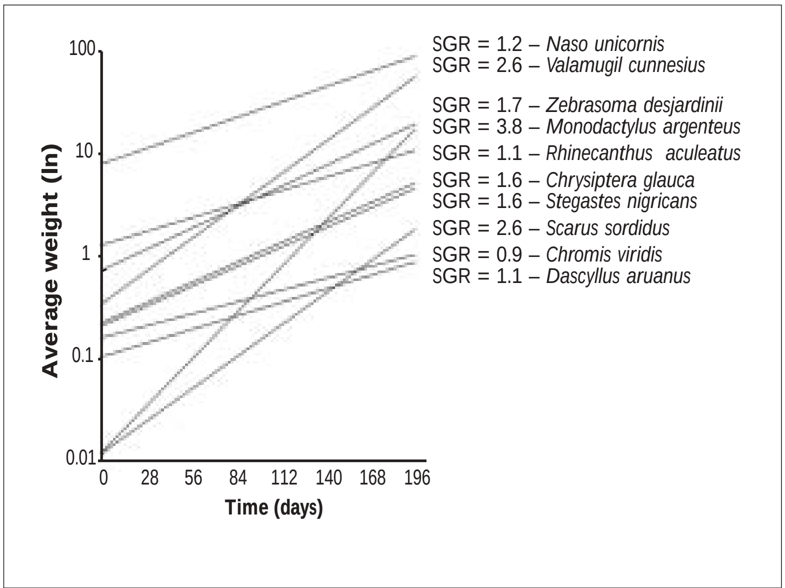

Figure 2. **Linearised growth curves, expressing the growth of the 10 species studied and their specific growth rate (SGR), expressed in per cent per day.**

Table 6. **Number of specimens sampled and parameters "a" and "b" in the length-weight relationship $W = a \cdot SL^b$ for the 10 species reared (the fresh weight is expressed in g and the standard length in cm), with the coefficient of determination (R^2).**

Species	Number of specimens weighed and measured	Parameter a	Parameter b	Coefficient of determination, R^2
Monodactylus argenteus	374	0.046	2.96	0.99
Stegastes nigricans	380	0.036	3.16	0.97
Chromis viridis	176	0.074	2.30	0.87
Dascyllus aruanus	201	0.118	1.61	0.80
Chrysiptera glauca	223	0.090	2.41	0.93
Scarus sordidus	277	0.031	3.03	0.97
Valamugil cunnesius	380	0.025	2.95	0.99
Zebrasoma desjardinii	213	0.067	2.89	0.97
Naso unicornis	220	0.066	2.82	0.98
Rhinecanthus aculeatus	218	0.136	2.45	0.95

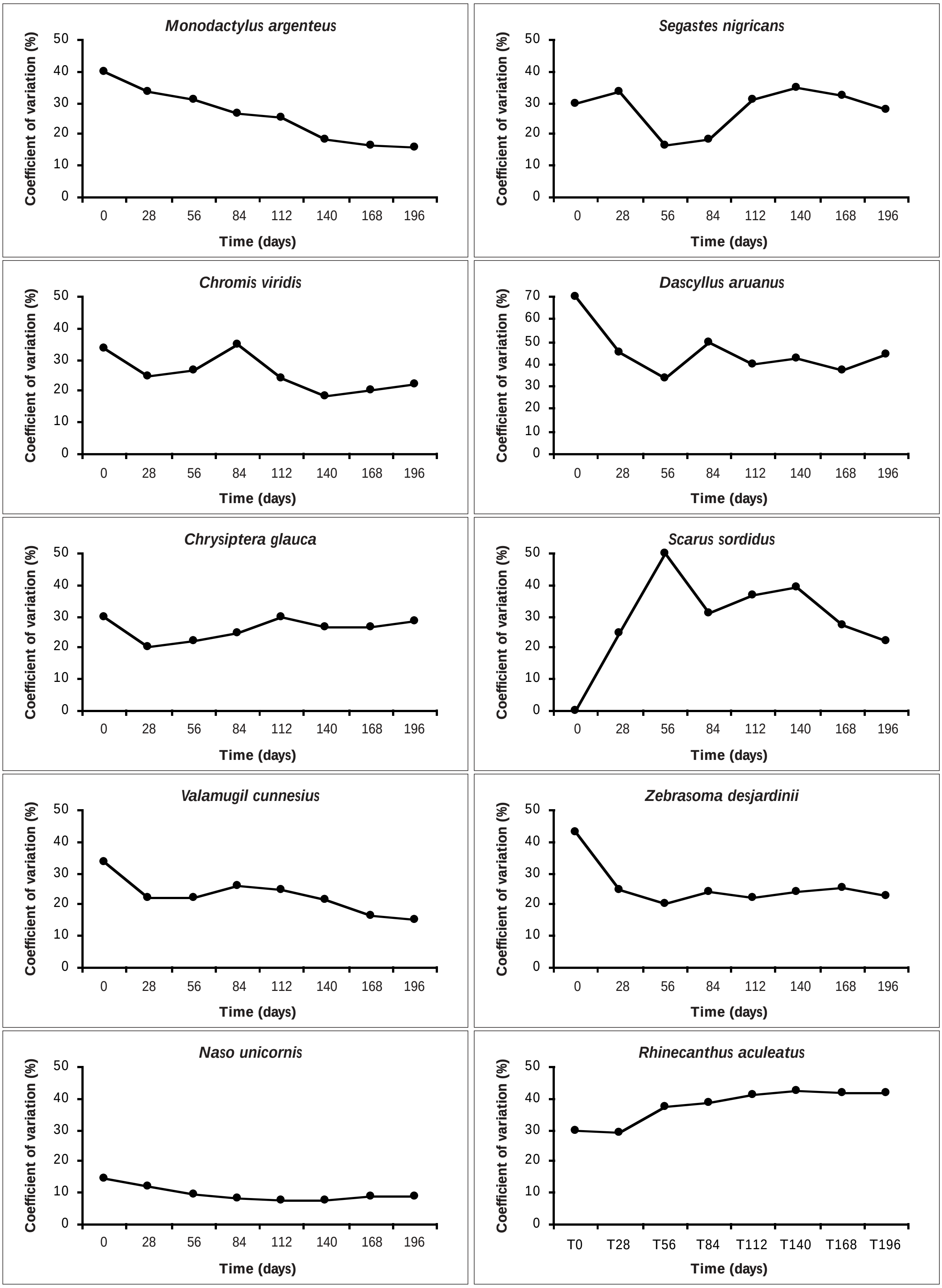

Figure 3. **Evolution of the coefficient of variation (CV) over time for the 10 species studied.**

group and therefore points to a degree of difficulty on the part of these fish to adapt to the experimental conditions.

Discussion

Survival of post-larvae in captivity

Ongrowing is a specific term in aquaculture referring to the stage during which fry weighing just a few grams are fed up to a weight of several dozen grams (Frelin 1994), which was generally the case in this study. The fundamental differences between ongrowing and growing concern, in particular, the susceptibility and fragility of juvenile fish to the biotic or abiotic environments. There is a very clear gradient, an increase in resilience and resistance from the very fragile larval phase to the adult phase (Barnabé and Lecoz 1987). Where marine fish are concerned, there are no precise data on survival at the various stages of growth. In farming conditions, the more fragile larval stages do not exceed a 70% survival rate, whereas at the adult and juvenile stages, 90% survival rates are routinely recorded, reaching as high as 98% with the Salmonidae, for example (Laird and Needham 1989). The purpose of our experiment was to assess the adaptation of certain species of coral reef fish to farming conditions using post-larvae captured in the natural environment. Apart from the aspects of growth and state of health of the fish that are difficult to assess, the survival rates show unambiguously how well these animals adapted to captivity. Of the 12 species studied, only two, *Gerres acinaces* and *Stethojulis albovittata*, showed high mortality rates at the very start of the rearing process and could not be kept alive beyond 84 days. The other 10 species were reared with survival rates varying from 60% to 92% after more than six months of captivity. Generally speaking, a result of greater than 70% is routinely obtained during the rearing phase, but it can be much higher and reach values close to 90% with certain coral reef fish species (Job et al. 1997). It would therefore be possible to use post-larval reef fish in farms and obtain survival results close to those achieved by the species regularly used in aquaculture.

Diet of coral reef fish post-larvae and juveniles

The feeding experiment results are only given on an indicative basis and could be used as a basis for more comprehensive studies on the food needs of young coral reef fish. It proved relatively easy to acclimatise and wean post-larvae caught in the natural environment. The diet that was used essentially covered the food requirements of carnivorous fish, although, of the species selected, three are considered at the adult age to be strict herbivores (*Scarus sordidus*, *Zebrasoma desjardinii*, *Naso unicornis*). They nevertheless rapidly adapted to a diet based on extruded protein-rich pellets. Some authors, such as Lassuy (1984), have observed that *Stegastes nigricans* could be carnivorous when juvenile and subsequently herbivorous. Others, however, such as Lefevre (1991), have observed that most young fish in the natural environment, especially the Acanthuridae, Siganidae and Pomacentridae, adapt early to an adult diet, although the feeding habits from the pelagic life stage remain important, with the constant presence of a large number of copepods in the stomach. The fish are therefore thought capable of major dietary adaptation at the juvenile stage. It remains to be demonstrated whether these feeding habits can be maintained in the long term within a production-oriented setting and whether this forced adaptation is reversible.

It is known that the metabolic activity of fish is inversely proportional to its size. Small fish show more rapid growth in terms of daily weight gain and their protein needs are very high. We therefore naturally observed that the daily food ration varied depending on the size of the fish raised. In our study, the ration was very high early in the experiments, reaching 20% of the biomass with some species (*Monodactylus argenteus*, *Scarus sordidus*). It then seemed to stabilise, whatever the species considered, around a mean value of 2% to 4% of the biomass, after some 100 days of rearing. Although our results were obtained using only one type of feed, similar values are commonly found in the feeding tables for conventional aquacultural species and may therefore be considered valid for coral reef fish at the juvenile stage.

The conversion indices or conversion rates are of interest in terms of production when they are less than 3, as with trout, salmon, bream, wolf fish, turbot and eel. They are unfavourable with values from 4 to 8, as with tuna and amberjack (Barnabé 1991). The purpose of our experiment was not to obtain low conversion indices, but to gather data on the biology and adaptation capacities of coral reef fish. Low conversion indices were, nonetheless, observed with *Valamugil cunnesius*, *Zebrasoma desjardinii* and *Scarus sordidus*. As adults, these fish weigh up to several kilograms. Although further experiments on diet are necessary in order to validate our results, these species could perhaps become potential candidates for some form of aquaculture use. For other species, which may be less rewarding in terms of food–growth conversion, it may be that the diet was unsuitable. Low growth rates and high conversion indices, as with *Dascyllus aruanus* and *Chromis viridis*, may indicate that these fish were underfed or that they had difficulty absorbing the food offered. The natural diet of these fish essentially comprises zooplankton (Vivien 1973), which are rich in fatty acids (Sargent et al. 1989). Types of food other than those chosen in this experiment might therefore be more suitable for these species.

Growth of post-larvae and juveniles in captivity

An understanding of the growth of the various species is a basic requirement for research on population dynamics. Among other things, it provides the theoretical weight of a specimen at a given age and therefore makes it possible to assess the biomass of a species or group of individuals. For the 10 species considered in the study, the mean weight curves showed functions similar to the power type. In this study, they related only to a very limited period in the development of fish at the juvenile stage. It is therefore normal to obtain substantial weight gain, which subsequently levels off with age and becomes close to a sigmoid function, such as described in the models of Gompertz or Von Bertalanffy (Muller Fuega 1990).

The specific growth rates, which make it possible to more accurately assess the growth potential of the fish, in this study showed a certain amount of variability depending on the species considered. The best rates, indicating rapid growth, were obtained by *Valamugil cunnesius* (2.6%), *Scarus sordidus* (2.6%) and especially *Monodactylus argenteus*, which had a growth rate of 3.8% per day over a period of more than six months, indicating the favourable performance of this species in terms of juvenile growth. Routinely recorded values in aquaculture are between 0.5% and 3% (Barnabé 1991), and specific growth rates this high are rarely achieved. Values of 4% to 5% have been obtained with juveniles of *Morone saxatilis*, but only under particular experimental conditions (Harmon and Peterson 1994).

The data obtained on the weight and size of fish during growth allowed the determination of length–weight relationships, which are important in fishery science, particularly for estimating the biomass from length measurements. Such measurements are often obtained during fishery sampling and therefore concern adult fish of commercial interest. This study provides some information on length–weight relationships at stages of development that have not been the subject of much previous research. The “a” parameter depends on the range of measurements used and therefore the growth period considered; it is difficult to interpret comparisons made between studies. On the other hand, the “b” parameter, even if it is not calculated with the same type of length data, does give an idea of the fish’s development. If it differs much from 3 (less than 2.5 or more than 3.5), it can be considered as doubtful or based on too short of a length measure (Carlander 1969; Pauly 1997). Estimates of this constant, obtained in our study for the 10 species placed in aquacultural conditions, can be compared with data obtained for wild fish from various coral reefs (Table 7). A certain similarity between the various results is recorded, except perhaps for *Dascyllus aruanus*, *Chromis viridis* and *Rhinecanthus aculeatus*, which show a much lower weight than the fish observed in the natural environment. This can be taken to confirm that the species do not develop properly under the proposed farming conditions.

Concerning the resilience of the 10 species of post-larval coral reef fish studied, at least four (*Monodactylus argenteus*, *Valamugil cunnesius*, *Zebrasoma desjardinii* and *Naso unicornis*), tolerated the farming conditions quite well, whereas *Dascyllus aruanus*, *Chromis viridis* and *Scarus sordidus* showed adaptation difficulties. Other species, such as *Rhinecanthus aculeatus* and *Chrysiptera glauca*, showed individual weight deviations that increased with time. This is the predictable reaction of territorial fish, where one part of the group, comprised of dominant individuals, always grows more quickly than the others (Barnabé 1991). To limit this effect, periodic sorting is generally carried out in fish farming to separate fish with differing lengths or weights.

Conclusion

Generally speaking, our understanding of the first stages of development of tropical marine fish is still limited. This study provides some elements on the biology of a number of species on which little research had been done, and at stages of development that are poorly understood. The fact that we worked on new species and used a range of techniques under specific conditions made it possible to test, to experiment with and to improve rearing protocols. Barnabé (1991) remarks that, when particular methods are used for certain species, it is likely that they will prove effective for others also.

The purpose of this research project was to assess the adaptation capacities and aptitude for aquaculture of a number of coral reef fish species, starting from post-larvae captured in their natural environment. The best evidence that a species is suitable for farming is successful early rearing. Its ability to feed properly and to grow and survive in artificial conditions demonstrates definite acclimatisation capacities. This is the case for ten of the 12 species studied, for which the 196-day rearing period was successfully completed. Some, such as *Valamugil* *cunnesius* and *Naso unicornis*, may have farming characteristics suitable for food production, because they are large fast-growing fish with low conversion rates. Others, such as *Monodactylus argenteus*, *Stegastes nigricans*, *Zebrasoma desjardinii* and *Rhinecanthus aculeatus*, show high survival rates and might therefore also be suitable for use for a range of other production purposes.

Generally speaking, the ultimate goal of research on fish in captivity is to understand their biological cycle; this is particularly difficult for most marine fish, which undergo one or more very small larval stages, during which they are highly sensitive to external factors. It is for these reasons that few species are currently farmed with complete predictability, especially coral reef fish. This study shows that the rearing of post-larval coral reef fish is possible under conventional intensive farming conditions, which opens up new prospects in many areas such as aquaculture, research and aquarium-keeping. This practice may make it possible to produce fish from post-larvae captured at sea under controlled conditions (Williams 1996; Bell et al. 1999). Some authors also recommend systematic measures for the purpose of increasing reef productivity: the post-larvae captured would be immediately placed in farming facilities and reintroduced later into the natural environment, thus considerably increasing their chances of survival (Dufour and Galzin 1992; Beets and Hixon 1994).

Acknowledgements

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Table 7. Comparison of studies of the parameters "a" and "b" in the length–weight relationship $W = a \cdot SL^b$, for identical species and same-genus species.

Species studied or species of the same genus	Number of specimens measured	Measurement range (cm)	Type of length*	Parameter a	Parameter b	Study location	Author(s) and date
Monodactylus argenteus	374	0.6 – 9.0	SL	0.046	2.96	Reunion	Durville (this study)
Monodactylus argenteus		2.0 – 18.5	FL	0.033	2.92	New Caledonia	Letourneur et al. (1998)
Stegastes nigricans	380	1.3 – 5.8	SL	0.036	3.16	Reunion	Durville (this study)
Stegastes nigricans		0.7 – 12.6	TL	0.022	3.08	Reunion	Letourneur (1998)
Stegastes nigricans		2.5 – 12.5	FL	0.168	2.36	New Caledonia	Letourneur et al. (1998)
Chromis viridis	176	0.9 – 3.3	SL	0.074	2.30	Reunion	Durville (this study)
(related sp. - *C. atripectoralis*)		3.5 – 9.0	FL	0.020	3.21	New Caledonia	Letourneur et al. (1998)
Dascyllus aruanus	201	0.9 – 4.1	SL	0.118	1.61	Reunion	Durville (this study)
Dascyllus aruanus		2.3 – 9.0	TL	0.028	3.03	Reunion	Letourneur (1998)
Dascyllus aruanus		2.4 – 6.5	FL	0.071	2.63	New Caledonia	Letourneur et al. (1998)
Chrysiptera glauca	223	1.1 – 5.5	SL	0.090	2.41	Reunion	Durville (this study)
Scarus sordidus	277	0.6 – 4.6	SL	0.031	3.03	Reunion	Durville (this study)
(related sp. - *S. frenatus*)		10.6 – 29.5	SL	0.027	3.06	Australia	Choat and Axe (1996)
(related sp. - *S. ghobban*)		6.8 – 49.5	FL	0.016	3.04	New Caledonia	Letourneur et al. (1998)
Valamugil cunnesius	380	2.2 – 16.6	SL	0.025	2.95	Reunion	Durville (this study)
Valamugil cunnesius			SL	0.016	2.88	South Africa	Van Der Elst (1981)
Zebrasoma desjardinii	213	1.9 – 7.6	SL	0.067	2.89	Reunion	Durville (this study)
(related sp. - *Z. veliferum*)		4.0 – 26.5	FL	0.033	2.85	New Caledonia	Letourneur et al. (1998)
Naso unicornis	220	4.9 – 14.2	SL	0.066	2.82	Reunion	Durville (this study)
Naso unicornis		18.5 – 60.0	FL	0.021	2.98	New Caledonia	Letourneur et al. (1998)
Naso unicornis		6.5 – 10.8	TL	0.032	2.78	Reunion	Letourneur (1998)
Naso unicornis		5.0 – 45.7	SL	0.085	2.84	Australia	Choat and Axe (1996)
Rhinecanthus aculeatus	218	1.6 – 7.7	SL	0.136	2.45	Reunion	Durville (this study)
Rhinecanthus aculeatus				0.017	3.10	Micronesia	Smith and Dalzell (1993)

* SL = standard length, FL = fork length, TL = total length

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Is your fish "bent" and will it survive?

Jill St John[1]

Fish, like humans, can get "bent" when exposed to rapid changes in pressure during capture. The bends, or decompression sickness, is a syndrome associated with a rapid and extensive reduction in environmental barometric pressure (Philp 1974). Because the bends is caused by the application of basic physics to living organisms, it is reasonable to expect that fish suffer bends in a manner similar to humans. Bends has been studied in humans involved in deep-sea diving, high altitude aviation, and underground engineering projects since the beginning of last century. Indeed, the early theories of Haldane and associates (Boycott et al. 1908) are still used today for modelling decompression schedules. Most of our limited understanding of the effects of the bends in fish is based on our knowledge of the bends in humans.

Barotrauma is defined here as all the physical effects of rapid and extensive reduction in barometric pressure. Of the barotraumas, the bends is the most well known, but there are other types of barotraumas that affect both humans and fish. Although most of the barotrauma damage occurs internally and thus is invisible, there are some external symptoms.

"Bent" fish are most likely widespread in the live reef fish trade, as most of the species that have been examined were found to suffer symptoms of decompression sickness after capture from shallow depths of 10 to 15 metres (m) (see Histopathological studies, below). To increase your understanding and awareness of "bent" fish, I will explain how fish get "bent", describe other barotraumas in fish, and discuss some useful methods to both prevent pressure-related mortality and increase survival of fish suffering barotraumas.

Physical laws of nature: Boyle's Law

Laws of physics govern barotraumas in animals. Gases are highly compressible, and at constant temperature the pressure of a given volume of gas varies inversely to its volume (Boyle's Law). Sea pressure increases one atmosphere (atm) every 10 m of water from the surface. Thus, pressure increases will halve the volume of air in a balloon at 10 m, reduce it to one-third its volume at 20 m, and so on (Fig. 1). The balloon represents the swim bladder in a fish, which must be kept at a constant volume to maintain neutral buoyancy (Pelster 1997). As the ambient pressure changes, gas is moved in or out of the swim bladder, so when the fish swims deeper, gas is taken into the swim bladder from the bloodstream. The reverse occurs when the fish swims upwards in the water column. As the greatest change of pressure occurs in the top 10 m, most of the damage to captured fish occurs during the last part of their ascent.

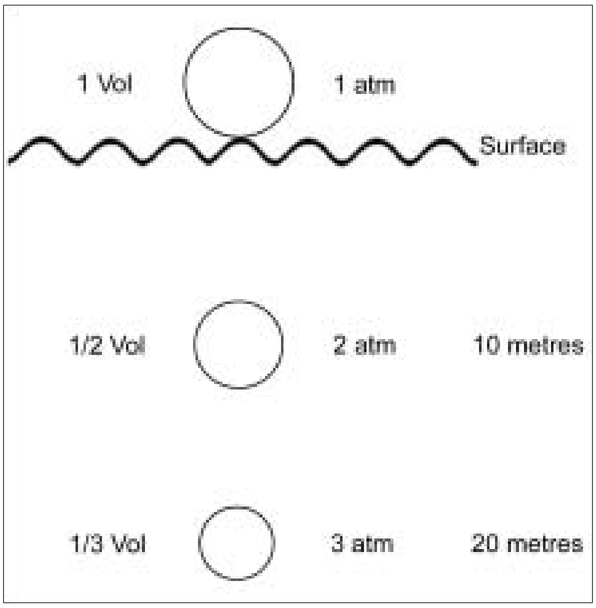

Figure 1. A demonstration of Boyle's Law: the effects on the volume of gas in a balloon as pressure increases with depth.

Partial pressures

As a fish descends, the pressure of air in the swim bladder equalises with the ambient water pressure, and the partial pressures of the individual gas components of the air increase. Air is made up of 79 per cent nitrogen and 21 per cent oxygen. Also, seawater, regardless of depth, is saturated (normal atmosphere as a reference point) in dissolved nitrogen

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(Saunders 1953). Nitrogen is present at a partial pressure of 0.79 atm at all depths in ocean seawater and it is the most common of the inert gases. Decompression sickness is caused by the formation of inert gas bubbles in the blood and tissues as the result of a sudden lowering of the ambient pressure. As the most common inert gas, nitrogen usually causes decompression sickness. All inert gases dissolve in the blood and tissue according to Henry's Law, where the dissolved concentration for any given gas equals its absorption constant multiplied by its partial pressure.

At any given depth a fish's body will absorb nitrogen gas through the gills and into the blood stream until equilibrium is reached and no more gas is absorbed (saturation). A decrease in absolute pressure results in a decrease in the maximum nitrogen that can be stored and nitrogen must be removed from supersaturated tissues according to Henry's Law. If decompression is slow, the excess nitrogen can be removed via the blood to the gills. During capture of the fish, however, rapid decompression saturates the rate of nitrogen elimination. Just like the formation of bubbles associated with opening a soft drink bottle, the nitrogen leaves solution from the blood and tissues as bubbles, until the concentration of dissolved nitrogen re-establishes equilibrium with the reduced partial pressure in the swim bladder. The formation of intravascular bubbles obstructs the blood stream, slowing the blood flow to the gills and further reducing the rate of nitrogen elimination. The stationary bubbles that accumulate in the bloodstream and tissues lead to the symptoms of decompression sickness.

The function of the swim bladder

In terms of Boyle's Law, swim bladders in fish are analogous to lungs in humans. Although some fish (physostomes) can release expanding air from their swim bladder through a pneumatic duct directly into the gut (Sauders 1953), other fish (physoclists) cannot. These physoclist fish have a well-developed capillary mesh that supplies blood to the swim bladder (Ferguson 1989) and is the interface for gaseous exchange. Thus, when ambient pressure reduces, the expanding gas in the swim bladder must be removed via the bloodstream.

All benthic reef fish can be assumed to have closed swim bladders, as physostomes are generally shallow freshwater species (such as carp and trout) that swallow surface air for buoyancy. Marine finfish exceptions are herring-type fishes, such as Atlantic mackerel (*Scomber scombrus*), which require greater depth flexibility and speed in moving through columns of water (Schmidt-Nielson 1997).

The effects of rapid depressurisation on the swim bladder

In many fish, especially benthic dwellers that do not usually swim up and down the water column, the drastic increase in the volume of gas during depressurisation at capture will inflate the swim bladder. The size of the inflated swim bladder at the surface increases with depth of capture and the swim bladder will rupture when the volume of gas becomes too great.

Symptoms of gas bubbles

During the rapid depressurisation at capture, gas bubbles formed from two sources (from gas exchange from expanding air in the swim bladder and from dissolved nitrogen in the body tissues) are released into the bloodstream. These intravascular gas bubbles can cause air embolism, blocking the flow of blood, and thus oxygen, to the tissues. As the blood supply from the capillary mesh of the swim bladder leads directly to the heart, large bubbles can cause a "heart attack" (Feathers and Knable 1983). Bubble formation in the tissues also leads to rupturing of cells, haemorrhaging and clotting, as well as other haemotological changes (Kulshrestha and Mandal 1982). If bubble pressure is great enough, the blood vessels can rupture, resulting in the haemorrhaging of blood into body tissue and the formation of clots at the damaged site.

Mortality studies

Most studies on the effect of barotraumas on both marine and freshwater fish have examined rates of mortality at differing depths because any release mortality reduces the effectiveness of legal minimum lengths as a management tool. Release mortality is an important component of fishing mortality in stock assessments. The general conclusion of research into the mortality of a range of fish species is that there is an inverse relationship between survival and capture depth (e.g. largemouth bass (*Micropterus salmoides*), Feathers and Knable 1983; red snapper (*Lutjanus campechanus*), Gitschlag and Renaud, 1994; snapper (*Pagrus auratus*), St John and Moran 2001). Thus, capture depth plays a critical role in the survival of released reef fish in both freshwater and marine environments due to barotraumas caused by depressurisation.

In one study, a hyperbaric chamber was used to simulate capture to study the effects of rapid decompression on largemouth bass (Feathers and Knable 1983). Fish depressurised from all depths showed some signs of barotraumas such as bloating or external haemorrhaging. Severe internal haemorrhaging and formation of gas bubbles in the blood occurred in fish decompressed from depths greater than 18.3 m. Mortality of largemouth bass was 40 per cent at the pressure corresponding to 18.2 m, and 47 per cent at 27 m. Survival was strongly correlated to the degree of internal damage although swim bladder inflation was not always correlated to internal damage. Total mortality was directly related to the magnitude of decompression.

In salmonoids, both the effects of the bends and the period between onset of signs of stress and death were considerably longer for larger fish than for small fish (Beyer et al. 1976). Bubbles were visible in the fins and tail of small salmonoids but not in the larger fish. Beyer et al. (1976) attributed their findings to the relationship between bubble size and critical blood vessel size. Although gas bubbles range in size in all fishes, a bubble of a given size is more likely to create an embolism or blockage in a small fish — with its narrower blood vessels — than in a large fish. Other evidence suggests that older and larger fish could be more susceptible to decompression sickness. For example, increasing age and body weight increases the susceptibility to decompression sickness in man (Shilling et al. 1976). The amount of nitrogen released can be expected to be proportional to the size of the fish and its proportion of fat, as nitrogen is more soluble in fat. The solubility coefficient for nitrogen gas in fat tissue (0.067, for biological fluids at 37° C) is five times larger than in lean tissue (0.012) or blood (0. 013, Shilling et al. 1976). In spite of these factors, size was found not to significantly affect the degree of barotraumas in largemouth bass (Feathers and Knable 1983).

In general, benthic dwelling fish that never swim near the surface are more susceptible to barotraumas as they do not appear to have the physiology to dump gas from swim bladders quickly and cope with intravascular gas bubbles. Whether or not other species that are more mobile within the water column have better systems to cope with rapid changes in pressure remains to be discovered.

Histopathological studies

In Western Australia, a release mortality experiment and histopathology studies have been done on two species of physoclist fish, snapper (*Pagrus auratus*) and Western Australian (WA) dhufish (*Glaucosoma hebraicum*) (Ashby 1996; Longbottom 2000; St John and Moran 2000; St John unpublished data). Caging experiments on release mortality of both species found that approximately 70 per cent of fish died at depths greater than 45 m (St John and Moran 2001, St John unpublished data). The pattern of mortality, however, differed between the two species at depths less than 45 m, as snapper were found to be more robust to barotraumas, with higher survivorship.

The histopathological studies examined acute damage to organs such as the heart, kidney, liver, spleen, and gills by assessing the degree of bubble formation, clotting, and haemorrhaging in these tissues (Ashby 1996; Longbottom 2000). WA dhufish were caught from two depths, below and above 20 m (range = 9 to 73 m), whereas snapper were caught from three depths shallower than 35 m: 10–15 m, 20–25 m, and 30–35 m. Bubbles, clotting and haemorrhaging were found in all WA dhufish from both depth categories, though damage was greater in the deep-water fish (Ashby 1996). Exopthalmia (haemorrhaging, swelling, and in extreme cases the rupture of the cornea) and rupture of the swim bladder also occurred in some deep-water fish.

Organ damage (including haemorrhaging, formation of small bubbles, and tissue displacement) occurred in snapper at all depths sampled (Longbottom 2000). The percentage of damage caused by haemorrhaging and tissue displacement, however, was significantly higher at depths greater than 25 m (Longbottom 2000). As mortality of snapper was relatively low at depths less than 35 m (St John and Moran 2001), many snapper survive a relatively high level of barotrauma. The degree of barotraumas in snapper was not related to fish size (length or weight) (Longbottom 2000). Between 10 and 40 m, mortality in WA dhufish was found to be higher than in snapper, and thus this species appears to be more susceptible to mortality from barotraumas.

Although there was no clear correlation between external symptoms of barotrauma and internal damage in red snapper (Gitschlag and Renaud 1994), swim bladder inflation was a significant indicator of internal organ damage in snapper (Longbottom 2000).

Condition, liveliness, and fish stress patterns of a fish on the deck of a boat after capture have not been found to be related to the degree of internal damage or survival (Neilson et al. 1989; personal observation).

Effects of inflated swim bladders

Overinflated swim bladders damage other internal organs inside the fish. Fish with severely overinflated swim bladders will be stressed in holding tanks because they are positively buoyant. They float upside down on the surface until the gases within their swim bladder have equalised to the surface pressure, which may take several hours.

Floating fish are more susceptible to mortality from heat stress or exhaustion from trying to swim normally. Venting or piercing the swim bladder with a sharp tube releases the gas and allows the fish to swim normally (see box on "how to vent fish" and Figs. 2 and 3).

Decompression of fish may be better than venting the swim bladder. For example, a study comparing the survival of yellow perch (*Perca flavescens*) between the two methods found that survival was higher in fish immediately returned to depth in cages (Keniry et al. 1996). Fish species that regularly show signs of severe barotraumas after capture may require decompression stops. Decompression stops can be done during or after capture (see box on decompression stops for "bent" fish). When losses to sharks or other predators are a problem during capture, decompression after capture is the best option for "bent" fish.

Summary

Although much more research into the problems of barotraumas in captured fish is required, the results of the research to date provide useful information for fishers in the live reef fish trade:

1. Most fish captured from depths greater than 10 m will suffer barotraumas.
2. Both the severity of barotraumas and mortality will increase with depth of capture.
3. The degree of barotraumas and rates of mortality for any given depth varies among species.
4. Generally, the extent of external symptoms of barotraumas reflect internal damage, but the condition or stress pattern of a fish on deck is not always related to mortality.
5. The size of the fish may affect the degree of barotauma.

As methods to cope with barotraumas vary among species and fishing methods, there will be no one method to treat "bent" fish. The following four points may help you develop the best practical procedures to treat "bent" fish.

1. Look for symptoms of barotraumas in all fish and note their severity (see Figure 4 and Table 1). *Tip: Keep a record of depth, handling methods, and degree of barotraumas for each fish to determine patterns of barotraumas in your target species.*
2. Decide on treatment: Venting is best for mild cases; decompression is best for more severe barotraumas. Kill severely "bent" fish.
3. Practice quick, sterile venting of swim bladders.
4. Keep records of treatment and outcomes of each fish to develop and refine decompression schedules for your target species.

How to vent fish

Venting is best done using a sterile, low-gauge, hypodermic needle (e.g. 1.2 x 38 mm). It can be inserted at a 45° angle under a scale below the lateral line near the tip of the pectoral fin (Fig. 2). After insertion, apply gentle pressure to the ventral surface of the fish to remove as much air as possible. Clear and sterilise the needle before re-use. Remember to keep fish out of direct sunlight during any procedure on deck and handle them carefully using wet towels and hands.

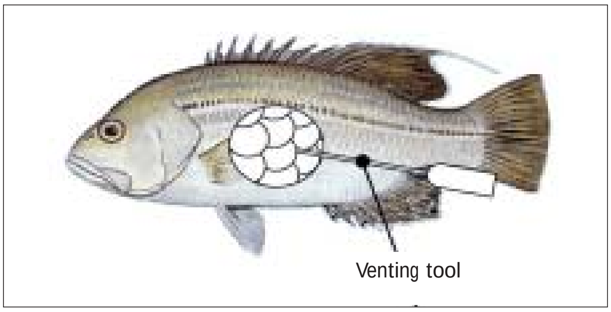

Figure 2. How to vent a Western Australian dhufish.

Figure 3. Venting an undersize Western Australian dhufish.

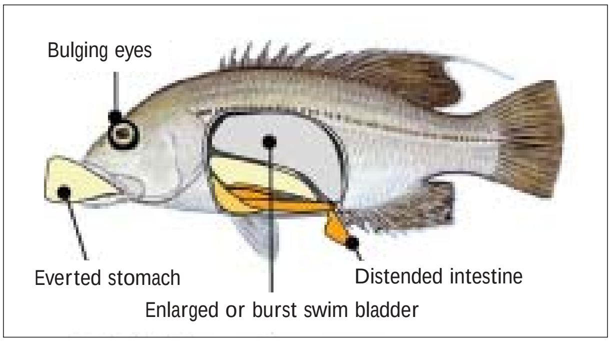

Figure 4. Symptoms of barotraumas in Western Australian dhufish.

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Decompression stops for "bent" fish

During capture, decompression stops may involve leaving a fish swimming on the line at 3 or 5 m below the surface for a few minutes while preparing a wet deck for capture. This method depends on the type of fish caught, as some species may tire and stress more the longer they stay on the end of the line.

Alternatively, a decompression stop or stops can be done after the fish has been brought on deck. This method may only be suitable on relatively stationary boats.

Although bent fish should be decompressed as soon as possible after capture, decompression at any stage should improve the health of bent fish. The exact decompression schedule would vary depending on fish species, depth of capture, and handling methods. Fish to be decompressed after capture could be put in a dark ventilated container and returned to specific depths for various times in weighted baskets or containers. These containers may need to be shark proof: made from metal and totally enclosed.

Table 1. **External symptoms of barotraumas, graded from mild to severe.**

	External Symptoms	
Degree of barotrauma	Associated with swim bladder	Associated with gas bubble formation
Mild	Inflated tight stomach	Small bubbles visible at the gills, fins, and eyes
Medium	Very inflated abdomen, distortion of scales	Some haemorrhaging at the gills and fins
Severe	Stomach everted from mouth, protruding eyes, distended intestine	Large bubbles and/or haemorrhaging at the gills, fins, and eyes

Market and industry demand issues in the live reef food fish trade

Frazer McGilvray[1] and Thierry Chan[2]

Hong Kong is well known throughout the Indo-Pacific as the major source of demand for the trade in live reef food fish and shellfish. Markets in all products are constantly evolving and changing. This paper outlines some of the changes in the demand side of this trade and highlights some of the emerging issues and programs that are being put in place to improve the practices that are still being carried out in some parts of the region, and to move the trade towards greater transparency and more responsibility in the future.

The International Marinelife Alliance (IMA) continues to play a major role in the region, working to reform the trade in live reef fish to one that is non-destructive and sustainable. In Hong Kong, IMA has successfully forged close links and maintained a productive dialogue with the Hong Kong Chamber of Seafood Merchants (HKCSM) and the Agriculture, Fisheries and Conservation Department (AFCD) of the Hong Kong Special Administrative Region (SAR) government. This dialogue is fundamental in securing accurate data and facilitating the progress of the industry standards project (described further below).

Wholesale and retail monitoring

Monitoring the imports of live reef food fish into Hong Kong continues, as does the collection of wholesale and retail prices for the most popular species. This has now been expanded to include the pricing of live lobster. IMA is increasingly concerned about the trade in other reef species, not only live finfish.

The monitoring of landings from Hong Kong registered vessels is a grey area when it comes to data collection, since unlike other vessels, they are not required by Hong Kong law to declare their imports. This would be contrary to Hong Kong's status as a free port. Information was collected by AFCD from merchants, but it was not thought to be statistically accurate, and only "ballpark" import figures could be obtained. These data were also reported in a way that the country of origin could not be determined. After consultations with AFCD, HKCSM and the University of Hong Kong, the data collection form was modified to allow easier and more accurate information collation.

By improving the collection of data on the landings made by Hong Kong-registered vessels, an overall picture of the source, volumes and species composition of imports will be obtained. This information will be disseminated throughout the region to allow fisheries managers to better assess the production of live reef species from their particular countries.

Data collected from 700 seafood restaurants (about 140 restaurants are surveyed each month) show price trends from a retail perspective, as well as trends in consumption of particular species, as fish appear in tanks in greater or lesser numbers.

Figure 1. **Fish held in Maxim's restaurant, Hong Kong.**

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Table 1. **Wholesale (W) and retail (R) prices (USD/kg) from Hong Kong and southern mainland China (December 2002 unless stated otherwise).**

Species	Hong Kong SAR	Guangzhou, China	Shenzhen, China
Cromileptes altivelis	W = 60.2 R = 92.0	W = 84.7 (Nov. 02) R = not available	W = 73.3 R = 110.7
Epinephelus coioides/ *Epinephelus malabaricus*	W = 9.1 R = 20.8	W = 9.0 R = 18.8	W = 10.4 R = 24.8
Epinephelus fuscoguttatus	W = 23.7 R = 43.6	W = 15.0 R = 25.4	W = 16.9 R = 35.5
Epinephelus lanceolatus	W = 24.3 R = 46.9	W = 15.9 (Oct 02) R = 33.7	W = 16.4 (Nov. 02) R = 47.7
Epinephelus polyphekadion	W = 21.3 R = 37.5	W = 23.2 R = 35.5	W = 22.2 R = 37.5
Plectropomus areolatus	W = 24.1 R = 39.9	W = 19.5 (Nov. 02) R = 41.0 (Sep. 02)	W = 19.4 (Jun. 02) R = 41.0
Plectropomus leopardus	W = 35.1 R = 51.7	W = 44.1 R = 50.6	W = 33.6 R = 60.4
Cheilinus undulatus	W = 53.0 R = 87.0	W = 76.9 R = 70.3 *	W = 74.5 R = 105.0
Lutjanus argentimaculatus	W = 5.1 R = 15.2	W = not available R = not available	W = not available R = not available
Sample size for R	129	10	10

* Only large *Cheilinus undulatus* were found in retail outlets in December 2002. These sell at a lower price than the "plate size" fish that were found in the wholesale market.

Expansion of monitoring in southern China

Since January 2002, IMA has expanded its monitoring programme to include Shenzhen and Guangzhou in southern mainland China, including both the wholesale markets and the retail end of the trade. More than 50 per cent of the fish imported into Hong Kong are transshipped across the border (as opposed to direct importation) into mainland China, taking advantage of the lower taxation when fish are imported through Hong Kong. It is not clear how China's entry into the World Trade Organization (WTO) will affect this method of "indirect importation". By developing links with local governments and the merchants based in Guangzhou, IMA can build relations similar to those it has developed in Hong Kong. Some Hong Kong merchants already have facilities in southern mainland China and are assisting IMA in their China developments. Price data collected in Hong Kong and southern mainland China can be seen in Table 1.

It is reported that a great deal of fish from Vietnam are shipped into mainland China directly, but further information is very difficult to obtain due to the area in northern Vietnam being controlled by the military. It is hoped that by working with importers in mainland China, a more detailed picture can be determined regarding these shipments.

Market shifts

There appears to be a decline in the rate at which reef fish are being imported into Hong Kong. There is also a shift towards cultured fish, but it is not clear whether these are from full-cycle culture or cage grow-out of wild-caught juveniles (aquaculture developments are discussed later in this paper). A contributing factor in this shift may be the downturn in the economy (the Hang Seng Index, for example, fell 45 per cent between 1999 and 2002), with consumers now choosing lower priced (i.e. cultured) products. Cultured fish tend to fetch a lower price than those that are wild caught. As research in aquaculture results in an increase in the number of species of fish that can be successfully cultured full-cycle, we believe we will see a higher percentage of fish from this source in the market.

In the month immediately following the attacks on the World Trade Center and the Pentagon (11 September 2001), importers noticed a downturn in business of 45 per cent, as Hong Kong followed the global trend of rapid economic decline. Within the last 12 months, three chains of seafood restaurants have collapsed.

Hong Kong import figures for 2001 decreased by approximately 20 per cent from 2000, and 2002 figures seem likely to continue declining. However, imports of coral trout (*Plectropomus leopardus*) from Australia have increased, totalling more than 1000 tonnes in 2001, and a greater volume will probably be imported in 2002. Australia now produces more than 50 per cent of the coral trout (the most favoured fish on the market) imported into Hong Kong, and about seven per cent of all of Hong Kong's fish imports. For many years, the total annual catch of coral trout from Australia's Great Barrier Reef remained fairly constant, with a shift from dead fish and fillets for the chilled market to live fish for export. Figures for 2001 show an increase of 400 tonnes over the 2000 catch of coral trout. Seventy-five per cent of this increase was for the live fish market.

Putting a value on the trade is difficult, but for 2001, we believe Hong Kong imported approximately 16,000 tonnes of live reef fish, with a declared import value in the region of USD 300 million.

There is an established grouper fishery in Baja California, Mexico, where fish are trapped for the local market. There are proposals to tap into this source of groupers to supply the increasing demand in major North American cities for live fish, particularly in areas with large Chinese populations, such as San Francisco and Vancouver. Hong Kong merchants are highly knowledgeable about the trade as a whole, not just about production in the Indo-Pacific and imports to and through Hong Kong.

Transportation

There has been a shift in the mode of transportation, with more than 50 per cent of fish now transported to Hong Kong by air. This is a significant shift from the past, when the preferred method was by live fish transport vessels (LFTVs). An improvement in communication links and the use of large enclosed air or oxygen bins (Fig. 2) — rather than oxygen-filled bags shipped in polystyrene boxes — has facilitated this change. The number of fish that can be transported in a one-cubic-metre transportation bin is much greater than the number that can be transported in a similar volume of polystyrene boxes (an approximate ratio of 6:1). This maximises return on investment, as according to traders, mortality during shipping is reported to be less than 1 percent, and the boxes can be returned to the source country and re-used. It is thought that the use of airfreight can have a positive effect on the management of the resource, as smaller volumes of fish are taken from the reef. This is not to say that all reefs can sustain even minimal fishing pressure, and a precautionary approach should be adopted before considering any live reef fishery. Using airfreight, live fish can be transported to the market in volumes as small as 300 kg. Using LFTVs, a cargo of 20 tonnes of fish would have to be shipped. This amount of fish is generally collected as rapidly as possible, placing immense stress on areas of reef that may not support that intensity of harvest. Mortality while fish are held prior to shipment is often high, resulting in the need to catch more fish to supply the required tonnage. The feasibility of air transportation is, of course, dependent on the proximity of the resource to a suitable airport.

Photo: F. McGilvray

Figure 2.
One-cubic-metre airfreight bin.

Aquaculture

Aquaculture is apparently viewed throughout the region as a practice that will reduce pressure on reefs. However, this can only be the case if the culture is full-cycle (egg to adult) and does not use wild-caught juveniles for cage grow-out. There are many research and production facilities focusing quite specifically on full-cycle culture and investing great amounts of money in the development of technology. Taiwan still appears to be the major area for the development of aquaculture in the region, although significant progress has been and is being made in Indonesia and Australia. More and more marketable species are successfully being cultured, but high-priced species, such as coral trout, *P. leopardus*, and humphead or Napoleon wrasse, *Cheilinus undulatus*, still cannot be cultured. The highfin or humpback grouper, *Cromileptes altivelis*, can be cultured successfully and is being done so in many areas of the region. However, due to the small market share held by this species (0.15%), the financial viability of producing highfin grouper solely for the food market is questionable. More than 90 per cent of giant grouper, *Epinephelus lanceolatus*, on the market in Hong Kong is now from full-cycle culture.

Regional and international collaboration

During the last several years, IMA has built up a working relationship with the Asia-Pacific Economic Cooperation (APEC), particularly the

Fisheries Working Group (FWG), raising the awareness of member economies to the issues facing the coral reefs of the region. The benefit of working with APEC is that it is a regional body, and although it cannot directly alter national governmental policy or legislation, it can pressure those governments to "go along" with other APEC economies. It has given IMA an audience that it would not normally have been able to reach, and also allowed IMA to put forward its case for reefs, reef species and reef fisheries. As perhaps the only organisation working across "the chain of custody" in the region, IMA is in the position to provide information on all aspects of the chain, as well as up-to-date information on APEC's main focus, trade. This can provide APEC a sound basis for making decisions in its various working groups, as well as at the ministerial level. In this regard, the APEC FWG is currently funding a two-year project to develop industry standards in the live reef fish trade. Of major concern to FWG is the issue of "certification", which is seen as a barrier to trade. The development of these standards is in no way a certification scheme, but rather a voluntary plan of best practices for adoption by all stakeholders.

Following on from plans developed during a multi-organisation strategy conference held in Honolulu in 2001, a meeting was held in January 2002 in Hong Kong to discuss the development of industry standards for the live reef food fish trade. These standards are being developed in collaboration with The Nature Conservancy, Marine Aquarium Council and HKCSM through a multi-stakeholder dialogue. They will cover areas such as capture, handling, transportation, aquaculture, stock assessment and food safety. Further details of this project are discussed elsewhere in this issue.

Continued efforts have been made by IMA to disseminate market information on the live reef food fish trade to stakeholders and fisheries managers throughout the region. All IMA regional offices and collaborative partners (e.g. the Secretariat of the Pacific Community and various government fisheries departments throughout the Indo-Pacific) receive a monthly update of import volumes and wholesale and retail prices. Should anyone wish to receive these market updates, or any other specifics on the market, they should contact the authors.

Pacific Regional Live Reef Fish Trade Management Workshop

Being M.Yeeting[1]

Background

During 2001 and 2002, the Secretariat of the Pacific Community (SPC) implemented a regional technical assistance project on the live reef fish trade (LRFT), in partnership with International Marinelife Alliance (IMA) and The Nature Conservancy (TNC), with financial support from the Asian Development Bank (ADB). Activities included biological and LRFT activity assessments in a number of Pacific Island countries, provision of policy and technical advice to government fisheries management agencies, and the development of a variety of public awareness materials.

As part of this project, a regional workshop was held at The University of the South Pacific to:

- provide fisheries policymakers and managers in the region with information on activities and outputs under the project;
- elicit the views of participants – especially Pacific Island representatives – in order to share and learn from each other's experience in developing and managing the trade; and
- identify priorities for action on the policy and technical levels.

Government representatives from all SPC member countries and territories that had LRFT operations (either for food or aquarium fish) were invited. Some countries, particularly Fiji Islands and Kiribati, also had representatives from the industry. Scientists and economists familiar with the LRFT from academic and research institutions and non-governmental organisations were also present. Mr Thomas Gloerfelt-Tarp was present to represent ADB, the sole funding source for the project. In total, there were 50 participants, half of which were from the Pacific region, representing 11 SPC member countries that had LRFT operations.

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Workshop objectives

The aims of the workshop were to:

- provide participants with an overview of the biological, fisheries management, economic, and socioeconomic dimensions of the LRFT;
- provide information and provoke discussion on the relative costs and benefits of opening the LRFT, and the conditions under which the trade may or may not be a positive and sustainable option;
- explore and discuss key policy and management issues related to the LRFT in the region;
- review various other ongoing initiatives related to the LRFT in the region;
- provide input into the development of draft industry best practice standards for the live reef food fish component of the LRFT; and
- identify priorities for future technical assistance, policy development, and capacity building in the region.

The meeting included 11 sessions:

Session I:	Opening / introduction
Session II:	Overview of the live reef fish trade in the Pacific
Session III:	Pacific Island countries' LRFT experiences
Session IV:	Overviews of relevant LRFT initiatives
Session V:	The Australian experience
Session VI:	Key scientific concerns
Session VII:	Key management concerns
Session VIII:	Marketing concerns, certification and best practices
Session IX:	Mariculture: a potential solution?
Session X:	Pulling together experiences and lessons presented
Session XI:	Wrap-up discussions and formulation of outputs

After opening speeches, Dr Jimmie Rodgers, Senior Deputy Director-General of SPC, made a dedication in respect and honour of the late Dr Bob Johannes and the fisheries work he has done in the Pacific region. The recently produced awareness video "The Live Reef Food Fish Trade - Avoiding the Boom and Bust Syndrome?" was then viewed.

A global and regional overview of the LRFT (both aquarium and food fish), including current trends and some important issues affecting the future of the trade in the Pacific, was presented in Session II.

In Session III, Pacific Island delegates discussed the status of the LRFT in their countries, and problems and issues in developing and managing the LRFT. This information is important in directing future SPC efforts. Presentations by industry representatives from Kiribati and Fiji Islands were useful in revealing some of the problems faced by operators and how they cope with management conditions and requirements. The session concluded with a panel discussion that organised key issues and priority actions into four categories: a) management issues, b) biological issues, c) social issues, and d) economic issues.

Session IV reviewed some of the initiatives in the Pacific that dealt with various aspects of the LRFT, including:

- the ADB-funded SPC Pacific Regional LRFT Initiative, a collaborative project with NGOs, particularly TNC and IMA;
- TNC's LRFT work in PNG and Solomon Islands;
- Solomon Islands LRFT project funded by the Australian Centre for International Agricultural Research (ACIAR); and
- the capture and culture of coral reef fish project implemented jointly by ACIAR, Queensland Department of Primary Industries, and the International Center for Living Aquatic Resources Management (ICLARM).

Australia provides at least 90 per cent of the live reef food fish exported to Hong Kong from the Pacific and it is generally acknowledged as probably the only well-managed and seemingly sustainable LRFT operation in the region. Although the LRFT in Australia is very different from that in the smaller Pacific Island countries, there were some important lessons to learn. Session V was devoted to discussing Australia's experience.

Sessions VI, VII, and VIII dealt with scientific, management, and marketing (including certification and best practices) aspects of the LRFT. Experts in each of these areas helped clarify key issues and lead discussions of their implications for the sustainability of the LRFT.

Culture initiatives of both live food fish and aquarium fish were discussed in Session IX. Grouper aquaculture has had success in Asia, where most of the research has been conducted; it was therefore important to describe the Asian experience and discuss the feasibility of introducing such activities into Pacific Island countries.

The last two sessions of the workshop were committed to summarising key findings about the LRFT in the Pacific and prioritising areas for further action. Following is a list of those findings and recommended actions, followed by a list of specific concerns raised by the country participants.

Key findings and recommendations

- Awareness about the LRFT in Pacific countries is poor.
- Strong awareness-building programmes are required in most Pacific Island rural fishing communities where the LRFT is likely to occur. There is consequently a need to translate awareness materials into local languages.
- Financial obligations are the main driving force behind communities overexploiting their resources.
- Opportunity costs should always be considered in the process of developing the LRFT.
- There is a general lack of technical capacity and ability to conduct data collection and assessment of resources and to transform this information into good management options.
- Stock assessment methods need to be looked at carefully and improved before they are relied on by fisheries managers and decision-makers.
- Underwater visual census is a useful tool for making quick estimates of the resource.
- Some countries use trial fisheries to evaluate the feasibility of the industry.
- Transportation of live fish is one of the biggest problems in the region. The transport of live food fish by sea is wasteful because of high mortality rates, while opportunities to transport by air are limited for most countries.
- Environmental risks associated with transporting water (with fish) from one country to another seems to have been neglected and should be addressed.
- Ciguatera fish poisoning is an important issue that countries should consider when developing their live reef food fish industries.
- Most countries do not have LRFT development and management policies in place. Such policies are urgently needed in order to control the LRFT.
- Lacking information, a precautionary approach to managing and regulating the fisheries should be considered.
- There is a lack of infrastructure and funds at the national level to manage the LRF industry, as well as other fisheries in Pacific countries, so it is appropriate to consider community-based fisheries management options.
- In managing the LRFT, an adaptive management approach that encourages community involvement and that is aimed at maximising benefits for local communities, should be taken.
- There is a need to improve coordination among different authorities within a country in developing and managing the LRFT.
- The real costs of management, including the costs of monitoring and enforcement, should be evaluated as part of the process of establishing a LRFT industry.
- Programmes that use observers on LRF fishing and transport vessels should be developed, similar to the observer programmes used for the region's foreign tuna fisheries.
- The exploitation of rare and vulnerable species such as the humphead wrasse is not sustainable and should be banned.
- Cyanide fishing does not seem to be an important issue in the Pacific, but the targeting of spawning aggregations is. Targeting spawning aggregations can quickly lead to depletion of fish stocks and should therefore be discouraged or banned.
- Given the fast-growing economy of China, the demand for live food fish is likely to increase.
- Information on wholesale prices of live reef fish is an important need of local governments and communities. Such information can be maintained in a centralized database, such as the one being developed by SPC.
- LRF operations have not followed any standards with regard to post-harvest mortality, and there is much room for improvement.
- Certification and best practices standards may improve the quality of LRF products and reduce the waste associated with high mortality rates, but the implications of such schemes for local suppliers in Pacific countries are not known.
- Alternative income earning opportunities should be promoted, but in some communities, such opportunities do not exist. Ecotourism is one option, but is not readily accepted in most isolated communities.
- Mariculture of grouper species for the live food fish trade is not an option for Pacific countries because of the highly competitive sources in Asia. Mariculture could, however, be an option for the trade in marine ornamental species.
- Demonstration is needed of the feasibility of semi-aquaculture-based aquarium operations that collect larvae from the wild for grow-out.
- It is important to recognise that the Australian live reef food fish industry is very different from those in the small Pacific island countries and therefore what works for Australia might not work in the Pacific. It is based on a single species and all exports are made by air to Hong Kong.

Countries' specific concerns and needs

- There is a need for public awareness programs on all aspects of the LRF trades.
- There is a need for better ways of making politicians and decision-makers more sympathetic to the reality of the LRFT and the need to properly manage it.
- What should a country do when approached by a LRF operator?
- Countries have a need for clear and transparent

processes for investors wanting to start LRF operations.

- There is a need for the development of "rough rules of thumb" (requested to be prepared in time for the next SPC Heads of Fisheries Meeting) that would provide steps for making quick precautionary decisions – based on the limited information available – on whether new LRFT operations should be allowed or not.
- There is a need to review lessons learned in the LRFT and to compile case studies from the Pacific to show the pros and cons of having a LRFT and also to look at and learn from the past experiences of other industries, such as forestry and tuna fisheries.
- There is a need to establish and promote information exchange among countries (e.g. on good and bad operators), which can then made available to SPC member countries through SPC's central database.
- Communities need to be properly informed in order to make decisions, so targeted and appropriate awareness materials that communities can comprehend easily should be developed. Such materials should be made available in local languages.
- There is a need for information, such as management guidelines and information on investors, and such information has to be country-specific.
- SPC should prepare a package containing management guidelines and recommendations for regional government fisheries departments.
- Coordination among government departments should be strengthened and fisheries departments should become more involved when new LRF operations emerge.
- There is a need for information linkages between supply countries and Hong Kong, including mechanisms for cross-checking various sources of information. These links should involve reliable partners such as the Hong Kong government, the Hong Kong Chamber of Seafood Merchants, and IMA-Hong Kong. It should be noted that the Hong Kong government has already stated that if it is approached for information by supply governments, it will readily respond.
- Countries should proactively advise LRF operators of their requirements, such as through the Hong Kong Chamber of Seafood Merchants. This task could be undertaken by SPC rather than each country doing so individually.
- Market prices can be made available to countries on a timely basis through SPC, with the help of IMA-Hong Kong. Possible media include SPC's website and the LRF Information Bulletin. The issue of information confidentiality should be considered.
- Many Pacific Island countries do not have the management structures needed to address the LRF trades, and this fact needs to be addressed.
- There is a lack of capacity and resources, both human and financial, in fisheries departments, especially at the provincial and state levels.
- Countries should consider using and building on traditional/customary management approaches to address the LRFT.
- There are concerns about spawning aggregation sites and there is a need for a fact sheet on aggregations to be included in the TNC/IMA/SPC awareness package.
- Countries should consider using marine protected areas, aggregation site closures, and seasonal closures of LRF fisheries during spawning seasons.
- Information and guidance are needed with regard to options for using marine protected areas as a management tool. For example, what percentage of habitat could realistically be closed?
- There is a need for information on ciguatera outbreaks.
- Priorities for enforcement should be clearly defined at the national, provincial, state, and community levels.
- Enforcement is a political issue and money is needed to ensure that enforcement will be effective. Options for meeting the costs of management from external sources should be considered. For example, should there be mechanisms to transfer the costs of management to the industry?
- Enforcement of some controls is more expensive than of others. The relative cost-effectiveness of various management options needs to be considered; for example, controls on fish exports are relatively inexpensive to administer and enforce.
- Where fisheries management capacity is limited, partnership or co-management arrangements that involve non-governmental organisations, communities, and other government jurisdictions should be considered.
- There is a need to consider the development of vessel observer programs for LRF fisheries.
- Public awareness of rules is needed in addition to active enforcement in order to ensure compliance.
- The capacity of regional organisations such as SPC is limited. The strengthening of effective regional partnerships with non-governmental organisations and other regional and international organisations should be considered.
- With regard to mariculture, there is a need to strengthen the linkages between SPC's Aquaculture and LRFT programmes and for SPC to link with organisations and initiatives in

Southeast Asia, such as the Network of Aquaculture Centres in Asia-Pacific (NACA).
- The potential for gardening coral for aquaria should be examined.

These outputs indicate a number of priority areas of concern. At the top of the list is awareness about the trade in government (both at the political and technical levels), in communities, and among operators and investors. Secondly, and closely linked to awareness, is the need for specific kinds of information (e.g. successes, failures, fish prices, and the histories of investors and operators). The third is management capacity. This includes technical capacity, as well as resources such as staff, infrastructure, and funds.

It should be noted that some of these needs are already being addressed through several activities. These include the production of a handbook of fishery management guidelines for the live food fish trade, the production of a package of LRFFT awareness-raising materials for communities, the production of a handbook about ciguatera fish poisoning, the development of a regional LRFT database, a compilation of case studies of LRF operations in the Pacific, and various capacity building activities.

Acknowledgements:

SPC expresses gratitude to its partners, TNC and IMA, for their contributions to this very successful meeting. Many thanks are also given to the resource people and country participants for their presentations and active involvement in discussions, and to USP's Marine Studies Program for providing the venue and logistical support. And finally, thanks to ADB for providing the funds that made the workshop possible.

Live reef food fish trade – Pacific awareness materials project

Andrew Smith[1]

The Secretariat of the Pacific Community (SPC), The Nature Conservancy (TNC), International Marinelife Alliance (IMA) and the World Resources Institute (WRI) entered into a three-year Memorandum of Understanding in December 1999 to implement "The Pacific Regional Live Reef Fish Trade Initiative." The overriding purpose and goal of this initiative was to provide scientific, information, policy and management advice and assistance to Pacific Island countries and territories with respect to the live reef fish (LRF) trade. The objective of the initiative was for SPC, TNC, IMA and WRI to work collaboratively to:

- collect, assess and disseminate information on LRF fisheries and trade in the Pacific region;
- assist Pacific Island nations to develop and implement regional, national and local mechanisms, policies and management strategies that promote or foster sustainable practices in the LRF fisheries;
- provide training and capacity building to Pacific Island nations for sustainable LRF fishing and fishery practices;
- strengthen the capacity of SPC's Marine Resources Division to respond to requests for technical assistance related to LRF fisheries from SPC member countries and territories;
- raise Pacific decision-makers' and communities' awareness and understanding of the LRF trade; and
- explore and develop appropriate opportunities for coordination and collaboration between the "supply" communities and "demand" markets to promote a sustainable industry that benefits local Pacific Island communities.

Within this initiative TNC took the lead in:

- compiling and maintaining an inventory of live reef food fish trade (LRFFT) awareness materials (all media); and
- developing relevant generic LRFFT awareness materials for various target audiences and disseminating them through SPC.

In order to establish common ground, set priorities, and begin development of these awareness materials, a workshop involving a broad range of participants was held in Papua New Guinea in May 2001. That workshop reviewed existing awareness materials, defined key messages and awareness goals,

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selected target audiences, and identified and prioritised the most important components for an awareness materials package. One output from the workshop was an inventory of all existing live reef fish trade related materials. This is now with the SPC Fisheries Information Section.

A preliminary set of the most urgent materials — information and fact sheets — was prepared and presented to the July 2001 Heads of Fisheries meeting at SPC in Noumea. In reviewing these preliminary materials after that meeting it was decided to modify them. As with any collaborative effort, a considerable amount of time and effort by a range of people was required to complete the materials.

The final set of awareness materials was presented at the Workshop on the Live Reef Fish Trade in the Pacific Region, 16–20 September 2002, at the University of the South Pacific, Suva, Fiji (see article by B. Yeeting in this issue for an overview of the workshop). These materials have now been printed and are ready for distribution by SPC. The awareness package includes:

- A presentation folder containing:
  1. An eight-page overview of the LRFFT in the Pacific
  2. Four two-page fact sheets on:
     a. Managing Our Fishery: Why is Management Critical?
     b. Managing Our Fishery: Why Assess and Monitor?
     c. Managing Our Fishery: What Do We Need to Know to Manage?
     d. Your Community and the Live Reef Food Fish Trade
  3. A poster with the 16 most valuable fish species on one side, and, on the reverse side, a diagram of the "chain of custody" of the fish (from the fishers to restaurants), a diagram of the distribution of revenue, and a map showing the history of the LRFFT in the Pacific.
- A six-minute video for decision-makers that outlines the main issues associated with the LRFFT.
- Plastic fish identification cards for the top 16 LRFFT species. These waterproof, pocket-sized cards include for each fish species a picture, the scientific name, English name, Hong Kong name, description, biology, reproduction, maximum size, importance, IUCN Red List threat status, whether poisonous or not, and the distribution in the Indo-Pacific.
- A glossy poster presenting the same top 16 LRFFT species, summarising the information given on the fish identification cards.
- Issues of the SPC Live Reef Fish Information Bulletin, which are also available online at: http://www.spc.org.nc/coastfish/News/LRF/lrf.htm

Under a related project, The Nature Conservancy is also preparing a series of destructive fisheries and live reef fish trade awareness materials for use in Papua New Guinea (PNG) and Solomon Islands, targeting communities. These materials will be ready for distribution in the first half of 2003, and include:

- Two posters for distribution in PNG and Solomon Islands through the fisheries agencies and other partners.
- A storybook covering lessons on the live reef fish trade and the effects of destructive fishing on village lives.
- A storyboard with cut-outs covering biodiversity and destructive fishing and a teachers' activity guide to support it.
- A story booklet for a humorous and light half-hour puppet show to engage children in the villages. The story booklet includes instructions on how to make the puppets and construct the scenes, and is simple enough for any school or community to perform.
- A video for community use.

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Workshop on Sustainable Marine Finfish Aquaculture in the Asia-Pacific Region

Mike Rimmer[1], Michael Phillips[2], Sih-Yang Sim[2]

The Workshop on Sustainable Marine Finfish Aquaculture in the Asia-Pacific Region was held in HaLong City, Vietnam, from 30 September to 4 October 2002. The workshop incorporated the end-of-project workshop for the Australian Centre for International Agricultural Research (ACIAR) project FIS/97/73, "Improved hatchery and grow-out technology for grouper aquaculture in the Asia-Pacific region", as well as a workshop on the development of standards for cultured marine finfish in the live reef food fish trade.

The workshop was held under the auspices of the Asia-Pacific Marine Finfish Aquaculture Network (APMFAN). APMFAN (formerly the Asia-Pacific Grouper Network, but recently expanded to incorporate marine finfish aquaculture generally) was formed in 1998 at an ACIAR-supported workshop in Bangkok. APMFAN is administered by the Network of Aquaculture Centres in Asia-Pacific (NACA) and has been funded to date by ACIAR and Asia-Pacific Economic Cooperation (APEC). The overall objective of APMFAN is to promote the sustainable development of marine finfish aquaculture in the Asia-Pacific region, through three main mechanisms:

1. Coordination of the regional research and development effort.
2. Promotion of, and support for, collaborative research activities.
3. Extension and training activities.

The overall objectives of the 2002 workshop were to:

- Provide detailed technical results of the ACIAR project, "Improved hatchery and grow-out technology for grouper aquaculture in the Asia-Pacific region".
- Provide a forum for young researchers involved in the development of sustainable marine finfish aquaculture in the Asia-Pacific region to present their results and interact with other researchers.
- Review the research and development needs for sustainable marine finfish aquaculture development in the Asia-Pacific region.
- Identify potential collaborative projects to assist the development of sustainable marine finfish aquaculture development in the Asia-Pacific region.

A one-day, follow-on workshop was held to initiate the development of standards for aquaculture of marine finfish for the live reef food fish trade (LRFFT), as part of an APEC-funded project to develop best practices for the LRFFT (see article by R. Kusumaatmadja et al. in this issue for an overview of the project and the outcomes of the workshop).

Participants included representatives from Australia, Brunei Darussalam, China, Denmark, Greece, Hong Kong SAR, India, Indonesia, Malaysia, Myanmar, Philippines, Solomon Islands, Thailand, United States of America and Vietnam, and represented both private and government sectors. The workshop was supported by the Government of Vietnam, ACIAR and the Australian Academies of Technological Sciences and Engineering (ATSE). Funding from ATSE under the Innovation Access Program allowed participation by young scientists from throughout the Asia-Pacific region.

The workshop focussed on recent improvements in production technology for groupers, particularly the outcomes of the ACIAR project. Among the specific topics presented and discussed in the workshop were:

- Optimising environmental conditions in newly hatched and pre-feeding grouper larvae to increase survival in hatcheries.
- The role of fatty acid nutrition in improving growth and survival of marine finfish larvae in hatcheries.
- Development of new fluorometric analysis techniques to assay the levels of digestive enzymes in marine finfish larvae and live prey organisms.
- Selective breeding of super-small (SS-) strain rotifers for hatchery use.
- Availability, cost and chemical composition of

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2. Network of Aquaculture Centres in Asia-Pacific, Bangkok, Thailand

locally sourced ingredients for marine finfish diets.
- Digestibility of key ingredients used to develop grow-out diets for marine finfish.
- Optimisation of the nutritional composition of marine finfish diets (protein, lipids, carbohydrate, vitamin C, etc.).
- The role of short-chain and medium-chain fatty acids in grouper diets.
- Socioeconomic impacts of marine finfish hatcheries in northern Bali, Indonesia.
- Case studies in the development of aquaculture to provide alternative livelihoods for fishers involved in unsustainable fishing practices (e.g. cyanide fishing).
- Techniques for capture and culture of pre-settlement post-larval fishes and invertebrates.

Immediate outcomes of the workshop include:

- Dissemination of recent research results to marine finfish aquaculture researchers, managers and industry from the Asia-Pacific region. Dissemination of results will be continued by placing workshop presentations on NACA's website (www.enaca.org/grouper/) and by providing each participant with a CD-ROM of workshop presentations.
- Identification of constraints to the development of sustainable marine finfish aquaculture in the Asia-Pacific region. Break-out groups identified the constraints to the development of sustainable marine finfish aquaculture and identified activities that needed to be undertaken to address these constraints. Participants then identified agencies that were already working on these issues and nominated agencies that were interested to work on them. This information will be collated by NACA and used to identify gaps in the APMFAN research program, and will provide funding agencies in the Asia-Pacific region with a framework for identification of priorities for sustainable marine finfish aquaculture development.
- Enhanced networking. The workshop enabled participants to discuss results and exchange ideas with other researchers and industry representatives working in related areas. A major constraint, identified at earlier workshops in this series, has been the poor information flow within and between the research and industry sectors involved in marine finfish aquaculture in the Asia-Pacific region. This workshop provided a valuable forum for researchers to develop new ideas and to evaluate new research processes, and for industry to gain a valuable update on the latest research results from across the region.
- Enhanced collaboration. The APMFAN has been highly successful in promoting collaborative research, and this workshop will contribute to this collaborative approach. In particular, this was the first opportunity to involve a number of Vietnamese researchers and industry representatives in such a workshop, and the workshop was particularly valuable to Vietnamese participants.
- Enhanced opportunities for young researchers. The involvement of young researchers from the Asia-Pacific region in the workshop provided them with the opportunity to interact with senior scientists, to experience a focussed international workshop, and to present their research results to an international audience. Generally, young researchers (particularly those in developing countries) have limited opportunities for involvement in workshops of this type. The involvement of young researchers enhanced the overall workshop by providing new and different perspectives on marine finfish aquaculture development in the Asia-Pacific region.
- Information provided during the workshop will be used for a strategy paper prepared by the Ministry of Fisheries on the future development of marine fish farming in Vietnam.

Overall, the workshop heard that there have been significant improvements in the production technology for marine finfish, particularly groupers, in recent years. Several species are now routinely produced in hatcheries and more hatcheries are being developed throughout Southeast Asia, particularly in Indonesia, the Philippines, Vietnam, and China. For more information on the workshop, including copies of presentations, visit :

http://www.enaca.org/grouper/

Developing industry standards for the live reef food fish trade

Rezal Kusumaatmadja[1], Charles Victor Barber[2], Paul Holthus[3], and Rod Salm[4]

LRFFT industry standards development background

In February 2001 a workshop was held in Honolulu, Hawaii to coordinate activities and formulate strategies among the organisations, agencies and other stakeholders concerned about the live reef food fish trade (LRFFT). The workshop identified — as one of the strategies — the need to develop a set of industry "best practice standards" for the LRFFT, covering the chain of custody from reef to restaurant.

In response to this, the International Marinelife Alliance (IMA), the Marine Aquarium Council (MAC), and The Nature Conservancy (TNC) agreed to work collaboratively with other stakeholders to develop a set of industry standards. This will be done over a two-year period from January 2002 to December 2003, with MAC providing the overall coordination. Support for the project is provided by the MacArthur Foundation, Packard Foundation, the Asia-Pacific Economic Cooperation (APEC) Fisheries Working Group, and the US Department of State.

The three organisations are uniquely positioned to undertake this activity. IMA's involvement in the live reef fish trade dates back to the late 1980s, IMA initiated the Destructive Fishing Reform Program in the early 1990s in the Philippines, and since then, IMA has played a leading role on the issue in Asia and the Pacific through its activities and / or presence in the Philippines, Indonesia, Vietnam, the Pacific, Hong Kong, Australia, Fiji, and other South Pacific countries. TNC helped raise the profile of destructive fishing practices associated with the LRFFT as a threat to marine biodiversity in 1995, and has focused its efforts on raising awareness of the problem and coordinating action among business, government, non-governmental organisations (NGOs), and scientific partners at both national and regional levels. MAC is the only organisation to have developed industry standards for a live reef fish trade (i.e. the marine ornamental industry) through an international multi-stakeholder process, and it will bring this technical and coordination experience to the project.

The goal of the project is to bring together stakeholders, and to build a consensus on what "best practices" are needed to ensure a sustainable industry, including sustainable reefs, fish stocks, and fishing communities. The project focuses on both wild-caught and cultured fish and covers standards and practices relating to assessment of fish stocks, capture and culture methods, holding, transportation, and human health and safety concerns.

Drawing from MAC's experience, the project will develop standards through an open multi-stakeholder consultative process, including, but not limited to: compiling existing information on current industry best practices, undertaking workshops and consultations in source and market countries, synthesising the results, developing draft standards for review, discussion, and revision by stakeholders, and field testing.

The resulting standards will be voluntary and will serve to minimise destructive practices and upgrade capture, culture, handling, and transport practices, thereby ensuring conservation of reef habitat for target species, and minimising human health threats from ciguatera poisoning.

The three organisations expect that the resulting standards will be of use to industry, government, and marine conservation organisations in ensuring that the live reef fish trade is a sustainable, high-value fishery that provides improved livelihoods for local fishers, a stable and healthy supply of live reef food fish to the market, and conservation of reef habitats, which are the basis for productive reef fisheries.

A project management committee has been established to oversee the implementation of the project's work plan and monitor the project's progress. The committee consists of Paul Holthus (MAC),

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2. International Marinelife Alliance, 1630 Connecticut Ave., NW Suite 300, Washington, DC 20009, USA. Email: cvbarber@marine.org
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4. Asia Pacific Coastal Marine Program, The Nature Conservancy, 923 Nu'uanu Ave., Honolulu, Hawaii 96817, USA. Email: rsalm@tnc.org

Charles Barber (IMA) and Rod Salm (TNC). To administer day-to-day standards development activities, a drafting team has also been formed, headed by Peter Scott (MAC) and comprising Patrick Chan (Hong Kong Chamber of Seafood Merchants — HKCSM), Michelle Lam (MAC), Frazer McGilvray (IMA), and Geoffrey Muldoon (IMA). Rezal Kusumaatmadja (MAC) serves as communications hub and "secretariat" for both groups, which, along with the representative of the APEC Fisheries Working Group, collectively form the project's "key partners" group.

The following are considerations that are being taken into account in developing the LRFFT standards:

Defining chain of custody

Based on HKCSM's experience, consumer and even restaurant buying preferences might not be influenced by industry adherence to standards. However, wholesalers are very interested in food safety and traceability (e.g. ensuring reliable information on where the fish come from and how they are handled, etc.). Approaching the standards development from this point of view would mean placing wholesalers in a position to demand standards compliance from their suppliers.

Verification of compliance

The goal of the project is to bring together all stakeholders and build common ground on steps that could be jointly taken to ensure a sustainable industry, noting that some system for verifying compliance with the standards will be essential in the implementation phase. The form that compliance verification will take has been left open for further discussion with relevant stakeholders as the process moves forward.

Industry and government buy-in

In order to get immediate industry and government buy-in in countries that are major sources of live reef food fish, it is important for the standards project to provide technical advice, based on concrete examples, concerning the ways that the standards might be implemented in the field. In Southeast Asia the initial focus should probably be on informing and involving governments in the development of the standards, since industry operators are already well-established there and the trade is ongoing. Without pressure of regulation from government, industry operators are unlikely to be very interested in changing their practices, particularly when this would involve up-front investments. It is also important to note that the purpose of the industry standards is not to "endorse" or allow the trade to open in areas where it does not exist (i.e. in some Pacific Island countries), but rather to ensure the trade is sustainable where it already exists.

Project progress in 2002

Standards development activities

Figure 1 shows the basic process for developing the standards. In the beginning of the process, the drafting team compiled existing information on current industry best practices and turned them into the draft standards. With additional inputs from major workshops, described below, the drafting team then developed the first draft of the standards and sent it to the expert review group in late November 2002. This draft covers three areas:

- The wild harvest of live reef food fish (i.e. resource assessment and fishery viability, fishery management and planning, fishing operations)
- Live reef food fish aquaculture

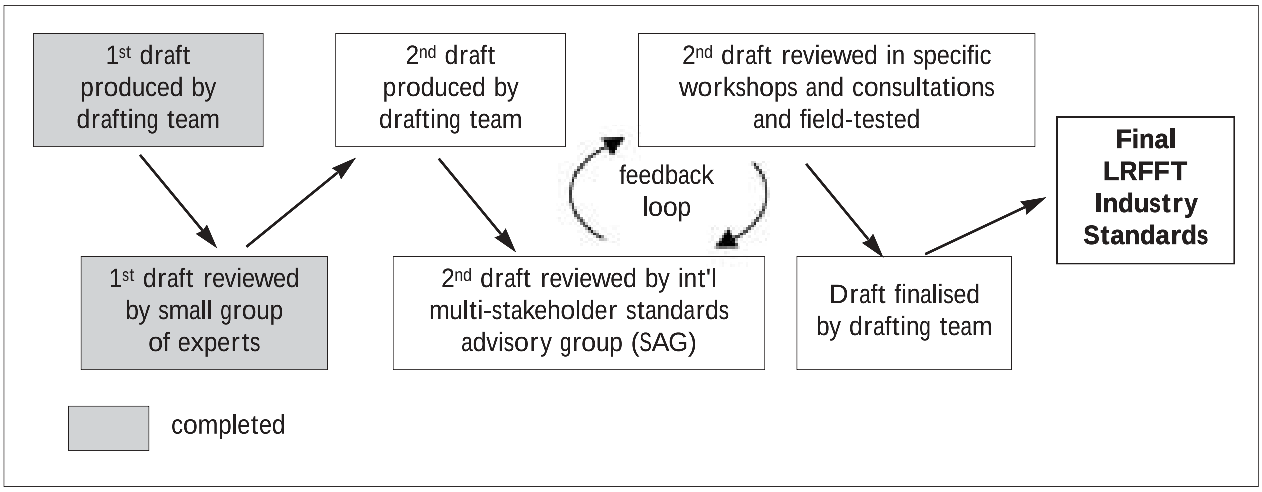

Figure 1. **Standards development process for the live reef food fish trade.**

- Importing, holding, distribution, and marketing of live reef food fish

The expert review group includes eleven members:

- C.T. Chueh, Taiwan Fish Breeding Association
- Hon. Nelson Kile, Minister of Fisheries and Marine Resources, Solomon Islands
- Rock Kwok, Agriculture, Fisheries and Conservation Department, Hong Kong
- Ted Loveday, Seafood Services Australia
- Randall Owen, Great Barrier Reef Marine Park Authority, Australia
- Joe Padilla, KKP (WWF Philippines)
- Jonathan Peacey, Ministry of Fisheries, New Zealand
- Mike Phillips, Network of Aquaculture Centers in Asia-Pacific (NACA), Thailand
- Bob Pomeroy, University of Connecticut, USA
- Yvonne Sadovy, Hong Kong University
- Kenneth Vy, Kenneth (H.K.) Aquamarine Products Inc., Hong Kong

As of early 2003, the drafting team is reviewing the comments submitted by the expert review group and will meet to revise the standards based on those comments. The key partners group will also meet in early 2003 to review and revise the project work plan.

Supporting activities

There are a number of supporting activities needed for the development of specific areas of information, which will contribute to standards development: 1) resource assessment and monitoring development, 2) economic analysis, 3) aquaculture standards development, and 4) consumer outreach. Among these activities, the two highest priorities are resource assessment and monitoring development, and aquaculture standards development. Consumer outreach activities will begin in the near future.

From the outset of the project, all partners agreed that scientifically robust, yet logistically and economically practical, methods for assessment and monitoring of live reef food fish populations and habitats and the impacts of LRFFT operations would be an essential component of the standards. To that end, the project partners held a workshop, "Developing Standards for the Assessment, Monitoring and Management of the Live Reef Food Fish Trade," in Townsville, Australia, 28–30 August 2002. The results of the workshop are reported by G. Muldoon in this issue.

Progress on aquaculture standards development was made at the "Workshop on Sustainable Marine Finfish Aquaculture in the Asia-Pacific Region," held in Ha Long Bay, Vietnam, 30 September – 4 October 2002. The workshop was organised by the Network of Aquaculture Centers in Asia-Pacific (NACA) and addressed the considerable ongoing research on grouper culture technology in the Asia-Pacific region (see article by Rimmer et al. in this issue for an overview of the entire workshop).

The key issues to be addressed by the aquaculture standards for the live reef food fish trade were identified and prioritised (see below) and initial draft standards and "best or better" practices were developed.

- Collection of wild fish for stocking (including larval/juvenile fish capture), including ensuring sustainability of supply (high priority).
- Improving survival of wild-caught larvae and juveniles (high priority).
- Development of hatcheries and practices for high-quality hatchery-reared fry (high priority).
- Chemical use in hatcheries and grow-out farms, including implications for product quality and the environment (high priority).
- Grow-out farm siting and habitat interactions (high priority).
- Waste control and effluent management (high priority).
- Feed supply and management (high priority).
- Fish health management (high priority).
- Food quality and safety (high priority).
- Socioeconomic issues, gender and poverty (medium priority).
- Alien species introductions and genetic implications (low priority).

The workshop agreed to widely circulate the draft standards among stakeholders, and to hold local farmer workshops in two or three selected countries for testing and development of aquaculture standards.

Conclusion

In its first year, the project has succeeded in bringing key stakeholders to the table to develop the beginnings of a "roadmap" for developing LRFFT standards for sustainability. Key scientific work on monitoring and assessment of wild capture, and on aquaculture, has been carried out through two major workshops. Most importantly, a group of stakeholders representing diverse interests — interests that have sometimes clashed in the past — are working and talking together to find common solutions.

In the second year of the project, the standards will go through a broadly inclusive Standards Advisory

Group (SAG) review process. During various consultation opportunities, the key partners group has been seeking and receiving support in the development of SAG from important stakeholders from government, industry, and NGOs. The project will conduct field tests to analyse the technical and economic feasibility of standards implementation in 2003. If the project proceeds according to plans, by the end of the year the standards will be finalised, along with supporting guidance documents to help implement them.

Of course, the real work of implementation will begin once the standards are disseminated and broadly adopted by relevant stakeholders. If LRFFT industry standards are to be more than a piece of paper, commitments from industry, donors, government agencies, technical experts, and marine conservation NGOs will be required to actually implement the best practices embodied in the standards.

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A workshop to develop standards for the assessment, monitoring and management of the live food fish trade

Geoffrey Muldoon[1]

Of the range of models used to achieve collaborative management of resources, voluntary codes of conduct and industry standards have been proposed as being more suitable for promoting practices that ensure effective conservation, management and development of resources with due respect for ecosystems and biodiversity. Many guiding principles of such codes (e.g. FAO Code of Conduct for Responsible Fisheries) recognise a sustainable fishery should be based upon:

1. assessment, maintenance and reestablishment of healthy populations of target species and ecosystem integrity;
2. the development and maintenance of effective fisheries management systems taking into account biological, socioeconomic and environmental aspects; and
3. compliance with national/local laws and standards and international understandings or agreements.

The recognition of the need for a broad-based set of industry "best practices standards" for the global live reef food fish trade (LRFFT) emerged from the *Collaborative Strategy to Address the Live Reef Food Fish Trade* workshop held in Honolulu in 2001.[2] A commitment to more sustainable fisheries outcomes in the Indo-West Pacific and Southeast Asia was reflected in the endorsement by those present to developing industry-wide standards to reduce the threats posed by unchecked expansion of the LRFFT.

As part of the LRFFT Industry Standards Development project being undertaken by the Marine Aquarium Council (MAC), International Marinelife Alliance (IMA) and The Nature Conservancy (TNC) (see story by Kusumaatmadja et al. in this issue), a three-day workshop was convened in Townsville, Australia, in August 2002.

The focus of the workshop was on developing practical standards to guide regional and national management agencies in producer countries in the development of sustainable management of their wild-harvest live reef food fish fisheries.

The main objectives of the workshop, convened by IMA (Australia) with technical assistance from MAC, were to:

1. summarise the main fisheries dependent and independent methods to collect and analyse data in tropical coral reef fisheries;
2. prescribe the application of these techniques to the LRFFT with emphasis on assessing initial fishery viability and the ongoing assessment and monitoring programs required to sanction or approve expansion of a fishery;
3. identify the management tools and strategies most appropriate for the LRFFT given capacity constraints; and
4. identify responsible practices of fishing operations in terms of capture and post-harvest handling and consumer safety.

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1. Program Coordinator, International Marinelife Alliance (Australia). Email: imaaustralia@impac.org.au
2. See Section 3.2, Graham, T. 2001. A Collaborative Strategy to Address the Live Reef Food Fish Trade. Asia Pacific Coastal Marine Program, Report # 0101, The Nature Conservancy, Honolulu, HI, USA.

The workshop was organised such that each of these objectives was captured under one of four themes. An additional theme, "Identifying actors and building capacity," was included to address key issues in relation to the realising these standards.

While this was primarily a technical workshop, participants comprised representatives from industry, government, the scientific community and marine conservation organisations from Australia, the Pacific and throughout Southeast Asia. By providing a forum for multi-stakeholder discussions, the workshop was able to build consensus on what "best practices" were needed to move the industry toward increased responsibility in terms of sustainable reefs, fish stocks and fishing communities.

Day one of the workshop focused on the main fishery dependent and independent methods for collecting data to assess and monitor the fishery status and their application to the LRFFT. The unique aspects of the LRFFT (spatial remoteness of collection areas and limited human, financial and institutional capacity) were identified as obstacles to collecting useable fisheries dependent data (catch and effort records) from fishers, middlemen and exporters. However, there are potential intervention points along the chain of custody where monitoring may be more effective, such as at the buyer or exporter level.

With the expansion of the LRFFT into new areas or countries often occurring rapidly, there was consensus that fishery independent methods such as underwater visual surveys (UVS) represented the most effective means by which to establish the potential for a LRFF fishery. UVS guidelines were established with respect to the techniques (e.g. belt transect, stationary counts, intensive searches) most suited for individual species targeted by the trade, mindful of their life history characteristics that require special consideration.

While recognising the superiority of UVS in initially assessing fishery viability, participants agreed that its limitations in estimating abundance, density and harvest limits meant reliance on UVS alone was inappropriate. Ongoing assessment and monitoring will need to utilise fishery dependent and independent techniques simultaneously. This calls for improved capacity of management agencies to collect catch and effort data from fishery participants, which will in turn require stronger collaborations between these agencies and non-governmental organisations (NGOs) to enhance that capacity.

While cognisant of the sovereignty of countries to exploit their marine resources for the LRFFT, participants emphasised that decisions to sanction or expand a LRFF fishery must rely on good scientific information, particularly biological parameters such as growth and mortality rates, size at recruitment to the fishery and size at maturation.

Fishery instatement and development

The meeting proposed the use of "Rough Rules of Thumb (RROT) for the Instatement and Development of a LRFF Fishery." These RROT, aimed at nations with limited fisheries assessment, management and monitoring capacity, recognised that acquiring site and species-specific scientific data to guide harvest limits will take a number of years. These RROT suggested precautionary guidelines for developing a LRFF fishery, including:

- the use of trial fisheries;
- minimum data requirements and techniques for collecting that data;
- collection of data from fishers engaged in artisanal fisheries and the LRFF fishery;
- limiting harvests to more productive species (e.g. *Epinephelus fuscoguttatus*, *E. polyphekadion* and *Plectropomus* spp.);
- bans on harvests of long-lived, threatened or ecologically important species and species economically important to non-fishing industries (e.g. dive tourism);
- setting initial harvest limits based on UVS estimates of standing stocks and known natural mortality rates;
- recognition and incorporation of existing customary marine tenure arrangements;
- closure of a minimum percentage of available reef area to exploitation for the LRFFT;
- prohibiting exploitation of spawning aggregations, such as through the use of seasonal closures; and
- undertaking a community cost-benefit analysis for all developing LRFF fisheries.

Fisheries management

The geographical, economic and political remoteness of many tropical small-scale fisheries and the lack of monitoring and enforcement capacity of governments means many conventional regulatory tools may not be suitable for the LRFFT, or may need to be adapted to achieve desired outcomes. With this in mind, on day two, workshop participants were asked to review a range of regulatory tools and practical management measures in terms of:

1. key factors for and impediments to their success;
2. the merits and shortcomings of each tool and preferred situation for their use; and
3. where along the "chain of custody" management intervention should be targeted.

Given the limitations described above, the use of input controls (licensing, effort controls, and seasonal closures) and zoning (spatial closures) were preferred to output controls (harvest limits and quotas) for managing the tropical inshore fisheries that usually support a LRFFT. Attaining long-term benefit from a LRFF fishery will require strict management and enforcement to alleviate potential negative environmental and social impacts. Ideally the management system should:

- adopt a precautionary approach in the presence of scientific uncertainty;
- quantitatively assess those resources to be targeted in advance of the onset of LRFF operations;
- require periodic assessments of fishing impacts on the biological status of the resource;
- achieve sustainable fisheries by protecting the ecological systems that support them;
- take account of current and historical demands from subsistence or local commercial fishing; and
- support and rely on the legal and customary rights of people dependent on fishing for a livelihood.

A fisheries management system for existing and proposed LRFF fisheries could be prescribed in the form of a fishery management plan, which was seen as requiring the inclusion of the following principal elements:

- Licensing
  - limits on number of licences, operation size and / or the size of holding pen for buyers and exporters;
  - separate licensing of locally owned fishing vessels and operators (buyers / exporters);
  - licence conditions to designate: fishing area, period for which licence valid, percentage of local ownership, crewing arrangements between operator and local fishers and recording and reporting requirements of licensee;
  - levying of licence or access fees to cover a percentage of monitoring and enforcement costs; and
  - access agreements between resource owners and fishing operator prior to granting licence.
- Monitoring and enforcement
  - data recorded at species level for live and dead product and bycatch species at all levels (fishers, middlemen and overseas buyers);
  - exports permitted only from designated airports or ports to facilitate monitoring of exports;
  - onboard fishery observers during both fishing and loading / unloading activities;
  - ban transshipments at sea and away from central collection areas;
  - recognise relevant community, provincial, state, national and international laws governing enforcement;
  - use traditional mechanisms of marine tenure and resource control to strengthen enforcement;
  - impose levies, fines or seizure of cargo for illegal fishing practices; and
  - practical recording tools (logbook, paybook) used by local fishers and foreign operators.
- Non-sustainable and destructive fishing practices
  - ban destructive fishing practices (poisons, explosives, traps, and hookah) in favour of hook-and-line fishing techniques;
  - ban targeting of spawning aggregation sites and prohibit the export of known aggregating species during known spawning seasons;
  - set conservative minimum and maximum size limits for main target species;
  - limit or ban exports of endangered and vulnerable species utilising where relevant international treaties (e.g. CITES); and
  - limit the capture and export of live wild-caught fingerlings for grow-out.
- Zoning
  - designate "no take" fishing areas through seasonal closures (spawning aggregation sites) or permanent closures (marine protected areas).
- Fishery status
  - periodic assessment of fishery resources and level of exploitation;
  - application of the precautionary principle; and
  - recognition of coincident LRFF fisheries and artisanal or subsistence fisheries.

The workshop proceedings have been synthesised into a comprehensive draft standards document and are currently with workshop participants for review, discussion and revision. The finalised workshop outcomes will be incorporated into the overarching standards documentation that embraces the entire chain of custody covering wild harvest, aquaculture and import, holding, distribution and marketing.

It is hoped that these standards and the supporting documentation will strengthen the efforts of the many government agencies and NGOs engaged in improving management of the LRFFT. They can be used to encourage more responsible fishing practices, and, where appropriate, provide for improved livelihoods for local fishers and a sustainable live reef food fish trade.

CITES, Santiago and conservation in the live fish trades

Yvonne Sadovy[1]

The recent CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora) meeting, held in Santiago, Chile, ended on some high notes for fish conservation after two exhausting weeks of debate, politics and a lot of sitting around. This was the 12th Conference of the Parties (CoP12). The term Parties refers to countries that are signatories to the Convention, each of which can send delegations to the Conference to vote on various proposals discussed for listing on CITES Appendices I and II. There are currently 159 Parties (although not all were present in Santiago, and Kuwait has newly become a Party).

What is the significance of the various CITES appendices and what marine species in the live reef fish trades are included? CITES is the only widely recognised, respected and implemented international instrument that deals with the sustainable international trade in wild species. It involves three appendices. The best known is Appendix I, which prohibits any commercial trade in species already endangered, such as tigers, gorillas or coelacanths. This appendix does not include species in the live reef fish trades. In practice, the most important appendix is Appendix II, which includes species that are not endangered but may become so if trade is not regulated. An inclusion on Appendix II enables international trade to continue provided that listed species are properly monitored and regulated to ensure that any trade (all of which requires a license or permit) is sustainable and comes from a legal source. Appendix II includes about 95 per cent of all species listed by CITES. Marine fish that are traded live and that are now (see below) on Appendix II are the seahorses (genus *Hippocampus*). Appendix III includes species at the request of a particular Party that already regulates trade in the species and needs the cooperation of other countries to prevent unsustainable or illegal exploitation. No marine fish traded live are on Appendix III. More details on CITES can be found at www.cites.org/index.html.

Given the growing global problems with marine fisheries (both live and dead) and increasing international trade, one of the most significant outcomes of the Santiago meeting was the inclusion of marine fish of significant commercial importance for the first time. Seahorses are sold dead for medicines, and alive for the marine aquarium trade. Serious declines in their populations and sizes have been noted in the last decade. This listing (as well as those of the basking shark, *Cetorhinus maximus*, and the whale shark, *Rhincodon typus*) represented a landmark decision because, until now, the Convention has not played an important role in any global fishery (live or dead). The humphead wrasse, *Cheilinus undulatus*, a small volume but high value species in the live reef food fish trade, was also proposed for Appendix II because of marked declines in sizes and numbers caught over the last 10 years and the increasing predominance in international trade of juveniles, amongst other problems. Although this proposal did not go through at CoP12, it had the support of the CITES Secretariat, of IUCN (the World Conservation Union), and fell just seven votes short of the required two-thirds majority for an Appendix II listing. Opponents to this listing included a number of the range states (i.e. countries that fall within the geographic range of *C. undulatus*). The major importer of this species, Hong Kong, China, had earlier submitted comments when reviewing the Appendix II proposal that the government could not support the listing for the humphead wrasse, in part because there was insufficient information on the species. They also argued that protecting this species would not reduce the use of cyanide. While humphead wrasse is widely caught with cyanide, the conservation problem and the key issue in the CITES context is not with this poison but with overfishing and lack of effective management in many of the key exporting range states. For more information on this species see www.humpheadwrasse.info.

It is important to examine why commercial fishery species, typically, have not been included on CITES appendices and why such arguments are no longer valid excuses to exclude fishes from CITES appendices. There are several reasons but probably three that are most important. I give them in some detail since all are relevant to the humphead wrasse proposal. The first is that only relatively recently are we coming to realise that commercially exploited

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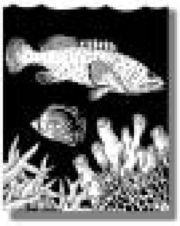
marine fish could possibly be threatened with extinction (or rather, that there is no reason to believe that they are any different from other plants and animals in this respect). Misperceptions linger, however. One Party at CoP12, which shall remain nameless, actually suggested in this global forum that it was obvious that 'primitive' groups such as the sharks could never become extinct because they had already survived for such a long time on Earth! No comment. The second reason that commercial fish have not previously been seriously considered for CITES listings is because for many, there are regional fishery management authorities or the Food and Agriculture Organization (FAO) of the United Nations that can, or at least could, deal with threats to the species. In such cases, it is argued, CITES is simply not needed. However, FAO does not actually manage fish and many regions have no, or at least no effective, regional fishery management authority. The third reason given is that there is insufficient information on most fish to properly assess their conservation status. While it is certainly true that aquatic marine species are difficult to evaluate in terms of their population status, fishery management is often based on similarly inadequate data as that used to determine conservation status and may represent the best available scientific data available. What is obvious, is that if there is clear indication of serious declines in landings or sizes, there is likely to be reason for concern and need for management or conservation action.

The Santiago meeting is considered to have been one of the most politicised of all CoPs, but it also made ground-breaking progress with several listings, including those of commercial fish. One thing is clear: for species that are heavily traded, vulnerable and not effectively managed, CITES is a critically important management and conservation tool. For many species, including our live-traded humphead wrasse, it may well be the only one. Indeed, an Appendix II listing for this species, which would still allow trade, albeit regulated, may be the only means of ensuring its sustainable use long into the future.



Protecting and managing reef fish spawning aggregations in the Pacific

Andrew Smith[1]

Destructive fishing practices that target key species and degrade fragile coral habitats are among the major threats to the viability of coral reef ecosystems. Many reef fish form aggregations at predictable places and times, frequently for the purpose of spawning. The nature of spawning aggregations makes them extremely vulnerable to elimination by overfishing. It can take as few as two to three years of intensive fishing on spawning aggregations to essentially eliminate breeding populations of fish. There is presently little awareness of — or capacity to address — this threat to the reef fish of the Pacific. The spawning aggregation phenomenon is rarely reflected in fishery management plans or the design of marine protected areas (MPAs).

The Nature Conservancy (TNC) has received grants from the US government's East Asia and Pacific Environmental Initiative, the David and Lucile Packard Foundation, and the Oak Foundation to improve the conservation of reef fish aggregation sites in a number of Pacific Island countries.

Over the next two years, the project will work to improve resource management and spawning aggregation site protection, increase awareness of these resources' vulnerability to overexploitation, and enhance the capacity to manage fish spawning aggregations and MPAs that incorporate these sites. There are three objectives:

1. to develop and facilitate the application of cost-effective management controls on the exploitation of aggregating reef fish resources,
2. to strengthen the capacity to assess, monitor, and manage reef fish aggregations, and
3. to raise the awareness and appreciation among stakeholders of the vulnerability of aggregating reef fish populations and associated ecosystems, the nature and significance of spawning aggregations, and options for improving management.

The project will build on partnerships and activities carried out during the past three years under the Live Reef Fish Trade initiative and the

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Protecting Coral Reefs from Destructive Fishing Practices project. Site- and country-level activities will focus on Pacific countries where TNC is presently working: Papua New Guinea, Solomon Islands, Palau, and the Federated States of Micronesia. The project will involve a number of locally based groups — both government and non-governmental — in those countries. The results and lessons learned will be adapted and disseminated for use throughout the Pacific region. The project will:

- develop and facilitate the application of cost-effective and practical monitoring and assessment protocols and an associated training manual for reef fish aggregations for use by Pacific Island fisheries officers and conservation practitioners;
- develop and have adopted relevant policies and guidelines for application at the local through regional levels for the assessment and management of spawning aggregation sites, also taking into account the larger issue of aggregating reef fish management away from these sites;
- develop and implement site-specific management strategies that incorporate customary management practices;
- develop appropriate design and management criteria for marine protected areas (including Locally Managed Marine Areas) for protecting both spawning aggregations and aggregating reef fish;
- increase the skills of our partners in reef fish aggregation site monitoring and assessment;
- develop regional and national "teams" composed of fisheries agency staff, locally based non-governmental organisations, and universities to maximise the resources available to identify, assess, and monitor reef fish spawning aggregations; and
- raise the awareness and appreciation among stakeholders of the limited productivity and vulnerability of aggregating reef fish populations and associated ecosystems, the nature and significance of spawning aggregations, and options for improving management.

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News from the Marine Aquarium Council (MAC)

First MAC certified collection area, collectors association, exporters, importer and retailers

Source: *MAC News,* 3rd Quarter 2002

The world's first to achieve MAC certification were confirmed by the London-based MAC accredited certification company IMS International in August. The Batasan Tropical Fish Collectors Association in Bohol Province, Philippines, and their collection area have been certified, as have the Manila-based exporters Aquarium Habitat, Aquascapes and HD Marineworld. IMS assessed the collection area and the organisations for their compliance with the appropriate MAC Standard in late June 2002. Collection areas are assessed to the Ecosystem and Fishery Management Standard; collectors to the Collection, Fishing and Holding Standard; and exporters to the Handling, Husbandry and Transport Standard.

This world first will be formalised in early October 2002 with the presentation of the MAC Certificate of Registration to the Batasan collectors. The Philippines Government support for MAC Certification and its commitment to backstop this with monitoring and enforcement will be evidenced by the participation in the ceremony by officials from the barangay (local community), municipality, province, and, possibly, national government.

Meanwhile, at the other end of the chain of custody, a Michigan import company and four Midwest retail facilities in the United States were assessed in mid September for their compliance with the MAC Handling, Husbandry and Transport Standard. The initial report by the Vancouver-based MAC Accredited certification company Shizen Megumi sound very promising, and in early October it is likely that these companies will become the first import and retail facilities in the world to realise MAC Certified status.

MAC Certified chain of custody ... *from reef to retail* becomes reality

Source: *MAC News*, 3rd Quarter 2002

With the expected confirmation of MAC Certification for a US importer and several retailers, the first MAC Certified organisms will be available in the marketplace for purchase by marine ornamental enthusiasts. To be MAC Certified, marine aquarium organisms must be collected from a MAC Certified collection area by a MAC Certified collector and pass only through MAC Certified facilities (e.g., exporter, importer, retailer) from reef to retail. In this way, hobbyists can be sure that the fish they buy are net caught from a managed collection area and that the certified marine aquarium organisms have been handled only by trained staff at quality facilities. Hobbyists and industry operators will be able to log on to the MAC website at www.aquarium-council.org to locate the certified facilities. Within these facilities, the MAC Certified organisms will be found in the tanks with the "Marine Aquarium Council Certified" label.

Retailers obtain significant benefits through MAC Certification

Source: *MAC News*, 3rd Quarter 2002

This summer, Aldwin Co, a business administration graduate student, conducted a cost and benefit analysis of MAC Certification for the US retail sector of the marine aquarium industry. The research showed that all of the companies involved in the study would attain significant savings and increased profitability by becoming MAC Certified and carrying MAC Certified marine aquarium organisms.

As part of the study, Co completed a detailed documentation and analysis of income and expenditures at four retail companies of varying sizes and types. A number of the companies that Co worked with found the research exercise useful in unexpected ways. For example, he helped them evaluate their true costs and what would be needed to ensure that their desired profit margins were realistic and / or accurately used. He also helped them better understand what they would need to do to become MAC Certified.

In addition, Co assisted in the design of a manual for an inventory management and point-of-sale software program that can be used by the retailers to support their MAC Certification compliance efforts. His work with the software package has filled a critical need for MAC and for the industry. MAC is pursuing the development of this software.

While the individual company reports are confidential, the general report "MAC Certification and US Retailers: Costs and Benefits" will be made available on the MAC website at www.aquarium-council.org. Co's internship was supported as a Packard Foundation Environment Fellow and organised by the MBA-Non-Profit Connection.

Pacific Region Update

Source: *MAC News*, 4th Quarter 2002

Fiji

In October 2002, MAC held the Regional Workshop on Certification Process and Procedures in Suva, Fiji, with representatives from export companies, government agencies, universities and conservation organisations. Following the workshop four Fiji exporters, all who have signed the MAC Statement of Commitment, worked with MAC to develop policy and procedures manuals and draft collection area management plans as part of their efforts to be certified by mid 2003. WWF Fiji also worked with one of the communities to help develop a collection area management plan.

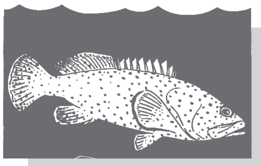
MAC also worked to raise awareness of the responsible aquarium trade with the tourism industry — an industry that has repeatedly called for closing the trade in Fiji. MAC made a presentation to the Mamanuca Hoteliers Association that was well received, with the MAC Certification process seen as a way to help clarify and resolve conflicts in use.

Vanuatu

A one-day multi-stakeholder workshop followed by a one-day workshop on MAC Certification was held in Port Vila in November. The workshops brought out issues from the tourism industry concerning reef degradation as a result of bad collection practices; the need to raise awareness, especially on the concept of certification; and the need for community support on reef management. Following the workshops, MAC worked with the three marine aquarium companies in Port Vila, all of which reaffirmed their desire to become MAC Certified.

Solomon Islands

The Solomon Islands Ministry of Fisheries and Marine Resources (MFMR), which is very supportive of MAC Certification, attended the Regional Workshop on Certification in Suva, Fiji in October, along with representatives of the Marau community and an environmental NGO from Solomon Islands. MAC has been working with communities participating in the aquarium trade in Marau Sound to help them become familiar with MAC Certification and the collection area management plan. The communities have requested training assistance to implement the MAC Standards.



Noteworthy publications

live reef fish

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Lai, L.W.C. and Yu, B.T. 2002. The evolution of the fry market in the marine fish culture industry of Hong Kong: An economic perspective. Aquaculture Economics and Management 6(3/4):191–214.

Pawiro, S. 2002. Live reef fish trade in Asia – update. INFOFISH International 6:33–37.

Note from the editor: This article describes some interesting new trends in the live reef food fish trade. Examples are given of the coral trout, *Plectropomus leopardus*, being sold at remarkably low prices in restaurants in Hong Kong and Malaysia. This and other trends are examined in light of recent shifts in both demand (particularly the general decline in demand for high-end seafood products in Hong Kong) and supply (particularly the increasing production of live coral trout in Australia). Also noted is the new trend of restaurants in Southeast Asia promoting a variety of imported seafood products. One example is a restaurant in Malaysia doing some "brand" marketing of coral trout from Australia's Great Barrier Reef. The author poses the compelling question of whether consumers' buying decisions are being influenced by publicity about the destructive fishing practices used in many live reef food fish fisheries and whether they will respond to promotions of live reef fish products known to be more environmentally friendly.

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The Network of Aquaculture Centres in Asia-Pacific reports in its newsletter (*NACA Newsletter* XVII(2), April–June 2002) that its publications are available for free download from the NACA website, www.enaca.org. Periodic publications include the *NACA Newsletter*, the magazine *Aquaculture Asia*, and the *Marine Finfish Aquaculture Newsletter*.

Wholesale Hong Kong prices of certain live marine fish species are now available on a weekly basis on the NACA website, www.enaca.org/Grouper/FishPrices/FishPricesIndex.htm, which obtains them from the Fish Marketing Organization, Hong Kong, www.fmo.org.hk/indexeng.html.

Publication of the journal *Aquarium Sciences and Conservation* has been discontinued. The contents of the final issue (vol. 3, no. 4), published in 2001, are given below. This issue is available at no charge from the publisher at: www.kluweronline.com/issn/1357-5325.

Aquarium Sciences and Conservation, volume 3, number 4 (2001):

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