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LIVE REEF FISH

The live reef fish export and aquarium trade

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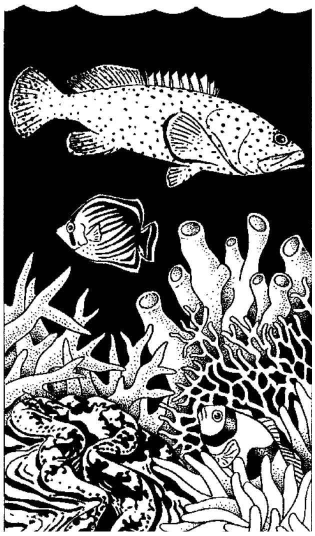
INFORMATION BULLETIN



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From the Editor

In the last year there has been considerable media attention given to the impact that Disney's animated movie, *Finding Nemo*, has had (or might have) on the marine aquarium trade and coral reefs. The movie is about the adventures of a young clownfish, Nemo, taken from his home on the Great Barrier Reef by a diver, and installed in a fish tank in a dentist's office in Sydney.

There have been reports of kids responding to the movie by flushing their aquarium fish down toilets in order to free them, reports of increased demand for aquarium fish, particularly clownfish, and stories about such increased demand leading to adverse impacts on coral reefs (see article in this issue by Being Yeeting and Kalo Pakoa about Vanuatu's marine aquarium trade and the effects of a particular news item on its management).

To give an indication of the influence *Finding Nemo* may have had on the marine aquarium trade and coral reefs, the name Nemo appears in the titles of two presentations made at the Marine Ornamentals 2004 conference, held in Honolulu in March (see the News and Events section for more on the conference), and in seemingly countless news items (other than movie reviews), with titles such as Flushing Nemo, Losing Nemo, Freeing Nemo, Stunning Nemo, Saving Nemo, Keeping Nemo and Nemo for Real.

The profusion of these news items probably reflects the public outreach efforts of organizations such as the Marine Aquarium Council and the United Nations Environment Programme as much as it reflects the magnitude of the movie's impact (the young actor Alexander Gould, the voice of Nemo, has partnered with MAC in its publicity efforts, and some stories were spawned by UNEP's efforts to publicize the release of its 2003 report, *From ocean to aquarium: The global trade in marine ornamentals*, available at http://www.unep.org).

Whatever their source, these stories concern the central questions that resource managers and scientists have to grapple with when

Inside this issue

it comes to fisheries for marine aquarium fish (and live reef food fish): Does the considerable global demand for these products offer viable economic opportunities to communities and nations such as those in the Pacific Islands? Are fisheries for these products currently managed so as to take best advantage of those opportunities while conserving the resource? If not, is it possible to do so?

After seeing all these news items about *Finding Nemo*'s impacts on the marine aquarium trade and coral reefs, I decided I had better see the movie for myself. First, I can report that it is a terrific movie. I can also say that it gives a dazzling and appealing view of coral reefs (although sometimes a scary one if you are a kid), and I can see how the movie could make people want to put a little bit of that dazzle into a tank in their home.

Although the movie does offer a moral lesson or two, the lessons are not really about whether it is good or bad to hold fish in a tank in your home. (OK, I admit there are lines like this one from Gill, a Moorish idol and patriarch of the residents in the dentist's fish tank, to Nemo: "Fish aren't meant to be in a box, kid; it does things to ya.") Still, the movie has clearly spurred many people to think a little harder about that fundamental question. I don't dare get any deeper into that question here — I'll let the present and future contributors to this bulletin answer it, along with the countless corollary questions in the realms of economics, biology, ethics and other disciplines.

Now, moving on from the cartoon world to the real world…

Dead fish are a major preoccupation of people involved in live fish fisheries (or they ought to be), as this issue demonstrates, particularly with respect to the marine aquarium trade. Christiane Schmidt and Andreas Kunzmann share their findings about post-harvest mortality rates and the causes of mortality from their intensive look at an aquarium fish export operation in Indonesia. Peter Rubec and Ferdinand Cruz provide an historical and industry-wide review of the same topic and outline their plans to conduct research aimed at reducing the mortality of marine aquarium fish during collection and transport.

As you read these articles and consider the double-digit per cent mortality rates that appear to be typical in the marine aquarium trade, it is useful to keep in mind the acceptable mortality limits in the standards established by the Marine Aquarium Council (MAC). These limits are basically 1% dead on arrival and 1% dead after arrival per species and per shipment for each link in the chain of custody. See the MAC web site (http://www.aquariumcouncil.org) for more details, including the "MAC Certification Mortality Allowance Information Sheet", which describes certain mortality allowances being made during the "development phase" of the standards.

This bulletin issue is relatively light on the subject of live reef food fish, but the article by Geoffrey Muldoon, Liz Peterson and Brian Johnston reviews recent economic events in the Asia-Pacific live reef food fish trade, including the impacts of last year's SARS outbreak. The article summarizes their plan to investigate the economic and market aspects of the trade.

This bulletin issue includes a few aquaculture-related articles. One is a manifesto by Suresh Job on the bright future of community-based aquaculture of marine aquarium fish. We also have progress reports from the field on the collection and grow-out of pre-settlement reef fish and crustaceans (by Cathy Hair) and on hatchery efforts for popular live reef food fish species (Bejo Slamet and Jhon H. Hutapea on humphead wrasse and Ketut Suwirya on leopard coralgrouper).

Tom Graham

Post-harvest mortality in the marine aquarium trade: A case study of an Indonesian export facility[1]

Christiane Schmidt[2] and Andreas Kunzmann[3]

Introduction

The use of destructive harvesting methods, the collection of unsuitable species, poor handling and husbandry practices, and the potential for overexploitation have raised concerns about the marine aquarium trade over the last decade (Barber and Pratt 1997; Johannes and Riepen 1995; Jones 1997; Sadovy 2002; Wood 2001). Most of these concerns are directly or indirectly related to high post-harvest mortality. The reduction of post-harvest mortality therefore plays a central role in the management of the trade. Because tropical fish are transported great distances to overseas destinations, and because many people are involved in their processing, there are a number of possible causes of post-harvest mortality. The reasons may be summarised as follows:

- Physical damage and use of cyanide during the catch, resulting in a higher risk of bacterial and parasitic infections and delayed mortalities (Hanawa et al. 1998).
- Poor handling, leading to stress and, thus, to a decreased resistance to continually present pathogens and diseases (Rottmann et al. 1992; Grutter and Pankhurst 2000).
- Inferior water quality during transport and in the tanks.
- Collection of species or juveniles that are almost impossible to maintain in aquaria.

There is a strong interest, motivated by sound economic and conservational reasons, in avoiding post-harvest mortalities. Every dying fish means a financial loss and a waste of fishing effort, as the fish needs to be replaced to fill the orders, thereby placing extra pressure on natural resources.

Although considerable action has already been taken to fight these problems, the management of the marine aquarium trade faces a lack of reliable data on post-harvest mortality (Holthus 1999; MAC 2001). Because of differences resulting from variations in product treatment around the world, it is nearly impossible to generalize globally about the level of post-harvest mortality that is typical in the trade.

Indonesia, a centre of global coral reef biodiversity, is a focus of the marine aquarium trade and the world's largest exporter of reef ornamentals. In order to provide information on the cause of post-harvest mortality, and to identify possible solutions to reduce mortality rates, post-harvest mortalities of marine ornamental fish were assessed in several deliveries made to and processed in an export facility in Indonesia over a six-month period.

Methods

The study was carried out in a single export enterprise that consists of numerous branch stations all over Indonesia, with three on Bali. Fish from middlemen and fishermen arrive at the branch stations, where they are unpacked, acclimatized and repacked. At the Goris branch station in northwestern Bali where this study was carried out, one fish supplier is a middleman located on Madura, who transports the fish by boat, landing at a nearby beach. This middleman buys fish from local fishermen on Madura who spend several days to weeks capturing the fish. Thus, the fish can be from regions such as Sulawesi or even the Philippines, and they may spend several days stored in plastic bags on board fishermen's boats, often exposed to direct sunlight, without sufficient oxygen and with only partial water changes. Before being transported to the Goris branch station, the fish spend at least one day at the middleman's facility on Madura. After the export company places an order, the fish are packed and brought to the branch station. During the deliveries observed in this study, transport time from Madura to the Goris branch station varied from 11 to 14 hours.

Other sources of fish for the Goris branch station are local middlemen and fishermen. In these cases, transport times are significantly shorter (1.5–2 hours) than for the Madura-based middleman. In the single observed delivery made by a local middleman, the middleman did not store the fish for several days before transporting them to the branch station, as was typical for the Madura-based middleman. The local middleman repacked the fish with a partial water exchange and refilled the oxygen before making the delivery by truck to

1. A version of this article was presented at the Marine Ornamentals 2004 conference, held 1–4 March 2004 in Honolulu, Hawaii.
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the branch station. Only dead fish were culled before transport to the exporter. Local fishermen transport their catch by moped to the branch station. In their deliveries, dead and injured fish are included. On arrival, the staff of the branch station controls the quality of the fish, and dead and injured fish are culled.

Injured fish are returned to the fishermen, or in the case of Madura, they are stored in separate tanks at the branch station in the hope of recovery. After acclimatization and repacking, the fish are transported by truck (3–4 hours) to the company's central station in Denpasar. Here the fish are acclimatized once again and kept in holding tanks until export — via Thailand and Singapore — to Europe and the United States.

In the course of this work, we observed the fishes' condition at each stage of processing, starting from the point at which they entered the branch station, up to the point they were exported from the central station. We followed and observed six deliveries of fish that were made to the Goris branch station and subsequently sent on to the central export station. Normally one delivery investigation took about 10 days, most of it consisting of the time the fish spent in the stock system at the central station (see Table 1). The six deliveries included a total of 2576 fish of 120 species — all finfish.

In this article, the six deliveries are named after the origin of the fish, followed by the transport time, in hours (h), from the place of origin to the branch station. They are listed below in the order they occurred.

Information was collected on numbers of fish dead on arrival (DOA), dead after arrival (DAA), and injured, as well as on the types of equipment used in the facilities, water quality (based on standardised tests) and handling, with the objective of examining possible stress factors causing mortality. DOA refers to every fish arriving dead or dying at the point the bags were opened at the branch station, whereas DAA refers to fish that die during the two acclimatisation periods and the stay in the holding, or stock, system until the point of packing for export. The term "losses" is used to refer to the sum of DOA, DAA, and fish injured to the point of being unmarketable. Observations of mortality and injury were recorded at the species level and apparent reasons for mortality were noted. The three most abundant species in terms of delivered numbers in total were *Chrysiptera parasema*, *Chelmon rostratus* and *Amphiprion clarkia*. Most abundant in terms of frequency during the six deliveries were *Chelmon rostratus* and *Zebrasoma veliferum*.

As additional background information, the management of the export company reported that it believes about 80% of the delivered fish are caught using cyanide, even though this is prohibited by law in Indonesia.

Results

Equipment and handling methods in the export facility

It was observed that the equipment and handling methods used in the facility were quite advanced. Possible negative effects of the equipment and the

Delivery	**Origin**
"Madura 13 h"	from company intern middleman on Madura
"Madura 14 h"	from company intern middleman on Madura
"Middleman 1.5 h"	from local middleman with fish from South Sulawesi
"Fisherman 2 h"	from local fisherman in Goris
"Madura 11 h"	from company intern middleman on Madura
"Madura 12h"	from company intern middleman on Madura

Table 1. The different processing stages at the export company and the timing for each of the six observed deliveries

	Branch Station					Central Station			
Delivery	Arrival	Un-packing	Acclimat-isation	Packing	Depar-ture	Arrival	Un-packing	Acclimat-isation	Days in stock system
Madura 11h	12.20	13.40	14.00–10.30	10.30	3.00	6.15	16.16	16.30–8.00	7
Madura 12h	11.00	11.15	11.30–17.30	17.30	3.30	6.30	8.30	8.45–13.00	7
Madura 13h	10.10	10.15	10.15–16.00	16.00	3.00	6.00	17.40	17.50–14.30	9
Madura 14h	11.40	14.00	14.00–13.00	13.00	3.00	7.30	8.45	8.50–13.40	7
Middleman 1.5h	9.30	11.15	11.15–10.30	10.30	3.30	7.00	10.50	11.00–14.30	8
Fisherman 2h	9.00	11.15	11.30–17.10	17.00	4.00	8.00	15.00	15.00–11.00	12

fish handling methods with respect to mortalities are noted in the following discussion.

Post-harvest mortalities

Total losses varied from 24–51%, by number, among the six deliveries, with mortality rates running between 10–40%. Injured fish made up a considerable part of the losses (Fig. 1).

Considering only the four deliveries from the middleman on Madura, a statistically significant correlation between transport time and DOA was found (r = 0.84). When taking all six deliveries into account, the correlation coefficient, r, dropped to a value of 0.43, which was not statistically significant. This indicates that transport time was not the only factor influencing DOA. Treatment and handling of fish in the period from catch to arrival at the branch station played an important role too. In all Madura deliveries, treatment and handling were presumed to be similar, which is reflected in the strong influence of transport time alone on DOA. The relatively high number (given the short transport time) of DOA in the middleman and fisherman deliveries can be explained by the influence of even more stressful treatment and handling.

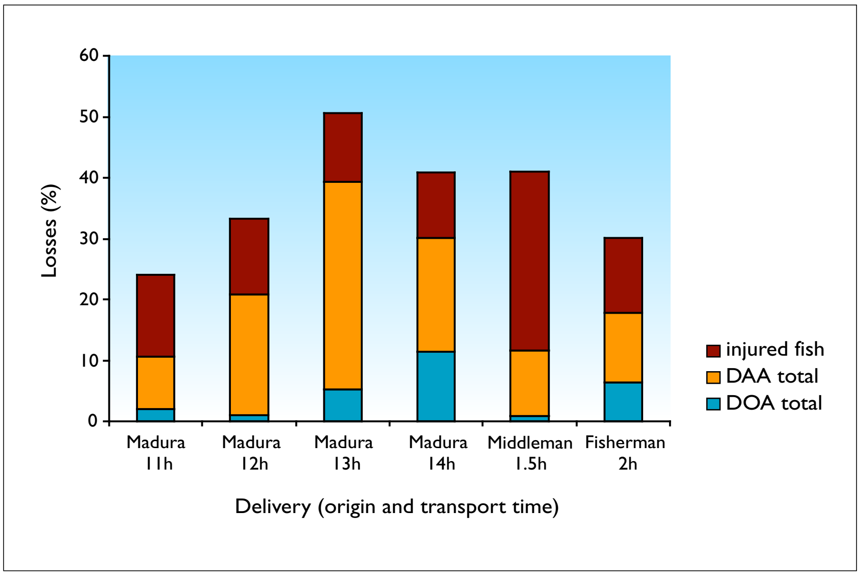

Figure 1. Losses of fish in each of the six deliveries, in percentage of the number of fish delivered to the branch station.[4]

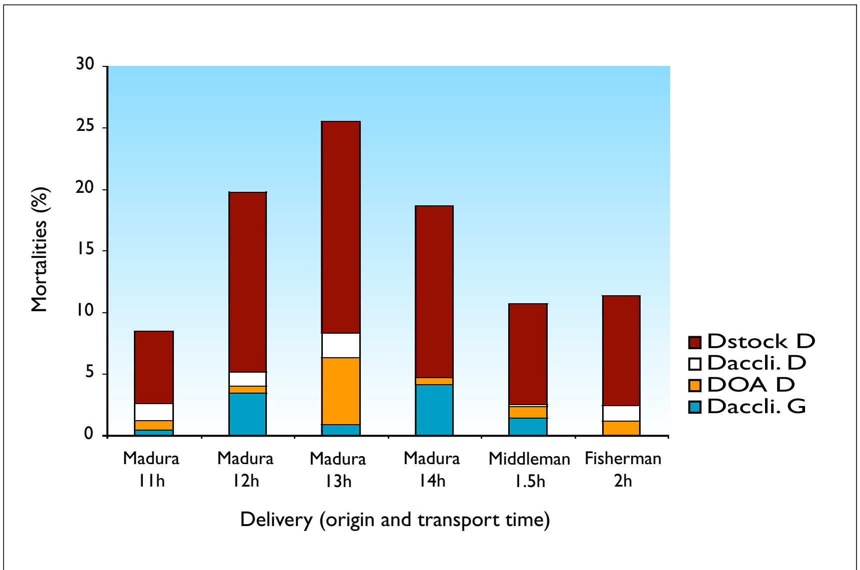

Figure 2. Mortalities at four processing steps after arrival (DAA), in percentage of the number of fish delivered to the branch station.

Most of the losses in four of the six deliveries were DAA (Fig. 1). DAA amounted to 68% of the total losses in the case of the Madura 13h delivery. The causes of mortality are reviewed by first examining the processing steps during which fish died. Figure 2 breaks down the DAA into four different processing steps. Mortalities occurred during the first acclimatisation in the Goris branch station (Daccli G), on arrival after transport to the central station in Denpasar (DOAD), during the acclimatisation in the central station Denpasar (Daccli D), and finally, during the stay in the stock system at the central station (Dstock D), which made up the largest part of DAA. Table 2 indicates the main causes of mortality in the stock system. Diseases caused by bacteria and parasites were the most prevalent causes.

A connection between cause of mortality and time of death was observed. The longer the duration of stay in the stock system, the stronger the influence of disease-causing bacteria and para-

4. Please note that in the Madura 13h delivery, mortalities occurring during packing at the branch station are excluded from Figure 2 while included in DAA in Figure 1.

sites. This explains the peaks of mortality that were frequently observed to occur after five to six days.

Mortality rates proved to be highly species dependent, but the species composition and numbers of fish varied widely among the deliveries, so it was difficult to rigorously identify differences in mortality rates among species. Generally, it was obvious that species not only differed in their mortality rates, but also in the processing steps at which mortality tended to occur. By application of a Chi Square test a significant correlation among species between processing step and mortality was found (Pearson chi square: 192.054; $p<0.001$). Some species died mainly during transport (*Chrysiptera parasema, Cromileptes altivelis, Ecsenius bicolor, Euxiphipops sexstriatus, Siganus vulpinus, Symphorichthys spilurus*). Others survived transport and died in the holding system (*Amphiprion sandaracinos, A. clarkii, Doryramphus dactyliophorus, Labroides bicolor, Labroides rubrolabiatus, Premnas biaculeatus, Pterois antennata*). A significant difference between these two treatments in the numbers of deaths they caused was found (Pearson chi square: 87,519; $p<0.001$). Fish of the subfamily *Amphiprioninae* started dying after four days in the stock system, caused by a *Brooklynella hostilis* infection that spread rapidly to almost all individuals in the subfamily. The cause of mortality in the majority of fish from other species was bacterial infection.

Table 2. **Causes of mortality in the stock system (percent of total).**[5]

Delivery	Disease parasites	Disease bacteria	Other
Madura 11h	27.3	68.2	4.5
Madura 12h	30.8	57.7	11.5
Madura 13h	27.3	22.7	50.0
Madura 14h	16.7	50.0	33.3
Middleman 1.5h	24.3	10.8	64.9
Fisherman 2h	72.7	13.6	13.6

Water quality

Water quality parameters are presented in the same sequence as they were measured for each delivery. Differences in water quality among tanks or transport bags for a given delivery are reflected in the range of measurements presented, which are, in all cases, the lowest and highest values measured. Tables 3 through 8 present the values measured for each delivery as the deliveries moved through the

Table 3. **Water quality parameters in the transport bags at the Goris branch station (random sample of ten bags of each of the three most abundant species in each delivery).**

Delivery	Salinity (‰)	Dissolved oxygen (mg L^{-1})	pH	Temperature (°C)	Ammonium (mg L^{-1})	Ammonia (mg L^{-1})	Nitrite (mg L^{-1})
Madura 11h	32.3–32.7	12.1–14.7	6.95 –7.25	29.2–29.4	4.0–8.0	0.05	0.15–0.25
Madura 12h	32.8–33.3	10.4–13.8	6.93–7.28	28.9–29.2	4.0–7.0	0.03–0.08	0.10–0.25
Madura 13h	33.3–36.5	6.98–8.60	7.13–7.42	29.1–29.3	1.0–10.0	0.01–0.19	0.10–1.00
Madura 14h	34.5–34.7	8.31–13.49	6.71–6.75	30.6–30.7	10–>10.0	0.04–0.05	0.05–0.15
Middleman 1.5h	34.1–34.3	16.01–18.61	7.01–7.36	26.3–26.9	2.5–4.0	0.02–0.04	0.00
Fisherman 2h	32.3–33.3	13.0–14.17	6.91–7.13	29.0–29.5	6.0–7.0	0.04–0.10	0.05–0.25

Table 4. **Water quality parameters in the two acclimatisation tanks at the Goris branch station**

Delivery	Salinity (‰)	Dissolved oxygen (mg L^{-1})	pH	Temperature (°C)	Ammonium (mg L^{-1})	Ammonia (mg L^{-1})	Nitrite (mg L^{-1})
Madura 11h	33.3	6.28–6.34	7.84	27.9	0.25	0.050	0.00
Madura 12h	34.3	6.08–6.20	7.16	27.6	0.00	0.010	0.01
Madura 13h	33.9	6.09–6.30	7.84	27.8	0–0.1	0.010	0.01
Madura 14h	36.2	6.26–6.32	8.13	27.6	0.25	0.050	0.02
Middleman 1.5h	36.4	6.42–6.47	8.02	26.0	0.20	0.050	0.01
Fisherman 2h	37.6	6.85	6.91	29.3	0.20	0.025	0.00

5. The "other" category indicates unidentified causes, which probably include poisoning by cyanide during the catch and its after-effects, or poisoning by copper, which is used for parasite prevention in the stock system.

facility, starting from the time they arrived in transport bags at the Goris branch station (Table 3) up to the point they were in the stock system in the Denpasar central station (Table 8).

In the transport bags at the branch station (Table 3), the deliveries showed great differences in the water quality parameters. Salinity and temperature in the transport bags of one delivery varied slightly by species, whereas dissolved oxygen, pH, ammonium and nitrite values showed larger variations by species.

In the acclimatisation tanks at the branch station (Table 4), all parameters, apart from dissolved oxygen, had the same values in the two tanks. Dissolved oxygen differed between the two tanks, depending on number of fish and species. Values of pH depended on the time of measurement as the pH changes during the process of acclimatisation (gradually increasing with time).

In the packing water at the branch station (Table 5), salinity differed only slightly among the deliveries; the lower salinities in the deliveries "Madura 11h" and "Madura 12h" were a consequence of a change in handling practices. These were the last two deliveries that were investigated, and they were done so after the management of the facility made a change in its water treatment instructions to its staff. Temperatures were strongly correlated with the climate in the vicinity, as packing water was taken out of an underground reservoir and put in plastic boxes before packing. The especially low pH value in the "Madura 13h" delivery is notable. Ammonium and nitrite were not detected in any of the deliveries.

In the transport bags arriving at the central station (Table 6), salinity and temperature showed similar values among species of one delivery. Dissolved oxygen, pH, ammonium and nitrite values differed considerably by species.

In the acclimatisation tanks at the central station (Table 7), salinity was quite similar among the deliveries; only the "Madura 13h" and "Fisherman 2h" deliveries had different values. In general salinity was low. Dissolved oxygen and pH values are dependent on the time of measurement, as oxygen is supplied during acclimatisation, so dissolved oxygen and pH can be expected to increase over time.

In the stock system at the central station (Table 8), salinity, temperature, pH, ammonium and nitrite were measured repeatedly over the length of the stay there, and at any given time, all these parameters had similar values at the point of the measurement in all six tanks that were used for holding the fish in a given delivery. Ammonium and nitrite were only measured once a week, but all other parameters were measured daily during the length of stay. Variations in the values were found from day to day

Table 5. **Packing water quality parameters at the Goris branch station.**

Delivery	Salinity (‰)	Dissolved oxygen (mg L^{-1})	pH	Temperature (°C)	Ammonium (mg L^{-1})	Ammonia (mg L^{-1})	Nitrite (mg L^{-1})
Madura 11h	29.2	6.07	8.46	27.5	0	0	0
Madura 12h	29.2	6.14	8.42	27.3	0	0	0
Madura 13h	34.2	6.28	8.05	28.6	0	0	0
Madura 14h	34.1	6.24	8.26	30.1	0	0	0
Middleman 1.5h	34.3	6.59	8.35	26.7	0	0	0
Fisherman 2h	33.8	6.55	8.28	27.9	0	0	0

Table 6. **Water quality parameters in the transport bags at the central station.**

Delivery	Salinity (‰)	Dissolved oxygen (mg L^{-1})	pH	Temperature (°C)	Ammonium (mg L^{-1})	Ammonia (mg L^{-1})	Nitrite (mg L^{-1})
Madura 11h	29.1–29.2	9.32–11.25	7.09–7.44	26.7–27.1	0–0.2	0	0–0.01
Madura 12h	29.0–29.2	9.30–11.40	7.06–7.56	26.9–27.4	0–0.1	0	0–0.01
Madura 13h	34.1–34.7	11.41–13.04	7.51–7.64	27.7–27.9	0–0.5	0–0.01	0
Madura 14h	34.4	11.40–14.40	6.34–7.24	28.7–28.9	0–4.0	0–0.03	0–0.05
Middleman 1.5h	34.0–34.3	13.72–15.42	7.05–7.43	27.6–27.7	0.25–0.9	0–0.01	0–0.025
Fisherman 2h	no data	no data	no data	no data	no data	no data	no data

Table 7. **Water quality parameters in the acclimatisation tanks at the central station.**

Delivery	Salinity (‰)	Dissolved oxygen (mg L^{-1})	pH	Temperature (°C)	Ammonium (mg L^{-1})	Ammonia (mg L^{-1})	Nitrite (mg L^{-1})
Madura 11h	25.3	5.57–6.19	8.28	25.5	0.2	0.02	0.02
Madura 12h	25.2	5.80–6.23	8.24	25.7	0.1	0.01	0.01
Madura 13h	28.2	5.73–6.31	8.16	27.5	0–0.2	0–0.02	0–0.02
Madura 14h	25.5	5.74–6.09	8.02	29.7	0	0	0
Middleman 1.5h	25.2	5.80–6.47	8.14	27.8	0.25	0.02	0.05
Fisherman 2h	26.1	6.50–6.62	8.27	26.8	0.1–0.2	0.01–0.02	1–0.025

Table 8. **Water quality parameters in the stock system at the central station. Ranges present the lowest and highest values measured in all six holding tanks over the length of stay.**

Delivery	Salinity (‰)	Dissolved oxygen (mg L^{-1})	pH	Temperature (°C)	Ammonium (mg L^{-1})	Ammonia (mg L^{-1})	Nitrite (mg L^{-1})
Madura 11h	26.1–26.5	5.42–6.77	8.30–8.44	26.6–28.3	0	0	0
Madura 12h	26.2–26.7	5.78–6.68	8.29–8.42	26.5–28.2	0	0	0
Madura 13h	27.4–28.1	5.98–6.57	8.15–8.27	27.0–29.0	0	0	0
Madura 14h	26.8–27.9	6.05–6.41	8.25–8.44	26.8–28.1	0	0	0
Middleman 1.5h	26.3–26.7	5.72–6.55	8.36–8.44	27.1–28.2	0	0	0
Fisherman 2h	26.0–26.2	5.94–6.49	8.41–8.47	27.1–28.4	0	0	0

and also among the deliveries. The largest differences, reflected in the ranges shown in Table 7, were 1.1 parts per thousand (‰) for salinity, 1.35 mg L^{-1} for dissolved oxygen, 0.19 for pH and 2.0°C for temperature. Temperatures changed by as much as 0.6°C during the course of a day. Concentrations of dissolved oxygen varied from tank to tank, from day to day and also among the deliveries. The values depended on the tank contents (number and species of fish) and on temperature.

Discussion

Some initial comments

The main objectives of this study were to estimate post-harvest mortality rates at different steps of processing, and examine the causes of the mortalities at the export facility. It was hypothesized that stress caused by treatment and handling was the fundamental cause of mortality. Stress was defined by Barton and Iwama (1991) as a state of reduced fitness. A stress-producing factor (stressor) leads to a change in the biological state of an organism, which can, especially if the stressor is chronic, strain the organism's adaptability, and ultimately result in its death. Different stressors and the resulting stress responses together have strong cumulative impacts on the fish, even though the single influences may be weak. Mortalities arise at each step of processing. They are related not only to the direct stressors acting at each step, but also to the stressors that affected the fish up to that point. Mortalities also depend on the resistance of the individual fish to stress.

Losses and mortalities in general

Looking at Figure 1, it is apparent that total losses differed considerably among deliveries, varying from 24–51%. Total mortalities (DOA and DAA together) ranged from 11–40%. This range is lower than the 30–40% mortality rates given by Vallejo (1997) for holding facilities in the Philippines, especially considering that four out of the six figures are within a range of 11–21%.

A closer look at the contributions of each of the three categories of losses (DOA, DAA and injured fish) shows that injured fish were a considerable part of the total losses (25–76% of the total, Fig. 1). The treatment of fish during transport to the branch station was observed to be rough (e.g. in the case of the deliveries from Madura, the bags were thrown on the beach where they lay unprotected in the sun). Mechanical influences while packing and transport can also injure fish. Although not specifically studied here, it seems clear that the handling and treatment of fish by workers in the export facility were more advanced than by the middlemen. Differences in the quality of treatment between the branch station and central station were observed as well. In the central station, handling was under the constant control of facility managers and guidelines were followed by the employees. In contrast, the quality of handling in the branch station seemed to fluctuate depending on the time and attitudes of the employees.

Dead on arrival

The percentage of DOA, which was influenced by the quality of the packing water, holding conditions before transport, handling during packing, and the duration of transport, ranged from 0.8–11%. The low value of 0.8% in the "Middleman 1.5h" delivery can be explained by the short transport time together with the fact that dead fish were culled from the delivery by the middlemen prior to their transport to the branch station. The high value of 11% in the "Madura 14h" delivery can be explained by the order of the Madura deliveries. "Madura 14h" was the second delivery observed. The authors' observations of the high numbers of DOA and generally poor condition of the surviving fish were passed on to the management, which resulted in the management passing instructions regarding quality control, handling and packing to the middleman on Madura. In the next observed deliveries by this middleman, the condition of fish on arrival was better and the number of DOA dropped considerably.

The negative influence of a long transport period can be compensated by better treatment and handling of the fish. But the catching method also has to be considered.

This leads us to an examination of the water quality in the transport bags arriving at the branch station (Table 3). The measured parameters can be compared to optimum and acceptable ranges for coral reef fish in aquaria given by Baensch and Debelius (1997) (the ranges given as "acceptable" refer to short periods only; they indicate conditions that are not acutely toxic):

- Salinity: 30.3–32.7‰ at 25°C
- Dissolved oxygen: 6–7 mg L^{-1}
- pH: 8.1–8.3 (optimum); 7.9–8.5 (acceptable)
- Temperature: 25°C (optimum); 22–28°C (acceptable)
- Ammonium: 0 mg L^{-1} (optimum); 0.01–0.05 mg L^{-1} (acceptable)
- Ammonia: 0 mg L^{-1} (optimum); up to 0.01 mg L^{-1} (acceptable)
- Nitrite: 0 mg L^{-1} (optimum); up to 0.05 mg L^{-1} (acceptable)

When comparing the parameters measured in the transport bags arriving at the branch station to these ranges, most of them did not fit into the acceptable ranges.

The dissolved oxygen values exceeded the acceptable range. The high concentrations can be explained by the use of pure oxygen for filling the transport bags, which can result in supersaturation up to 277%. Supersaturation can be harmful to fish and lead to gas bubble disease (Bassleer 2000), although this was not observed in this study. Oxygen concentration, together with pH, ammonium, ammonia and nitrite, is also a species-dependent parameter. The pH in all the transport bags in all the deliveries was lower than the acceptable range. In the transport bags water is polluted by faeces and exhaled carbon dioxide, so the pH can drop to undesirable levels over time. But since this is a long-term process the fish can adapt to the pollution and low pH level and can cope with it. Actually the low pH acts like a life insurance for the fish, as at this level most of the end products of protein metabolism are present in the form of ammonium, which is less toxic to fish than ammonia, to which ammonium is converted at higher pH levels. But at the measured pH levels, ammonium — and therefore also ammonia — concentrations are high and outside the acceptable ranges. The survival of the fish in the observed deliveries can be explained by the short period of influence of these high concentrations. But the relatively high ammonia concentrations were probably a factor that influenced the number of DOA. The same is true for nitrite. Another effect of ammonia is that at low levels it acts as a strong irritant, leading to skin and gill hyperplasia. Gill hyperplasia results in respiratory problems and creates ideal conditions for opportunistic bacteria and parasites to proliferate (FishDoc 2003). Mortalities related to these problems can also occur later in the chain of processing.

Dead after arrival

Most losses were DAA. The percentages of DAA among the deliveries varied from 8.5–34%. The total DAA was broken down into four different mortality rates related to different processing and treatment steps during the stay in the export facility (Fig. 2).

Death during acclimatisation in the branch station

Mortality rates ranged from 0–4% during this step (Fig. 2). Among the water quality parameters measured in the acclimatisation tanks, ammonium and ammonia appear to be plausible causal factors. Both parameters depend on the species composition and stocking density in the tanks. If tanks are overstocked, ammonium and consequently ammonia accumulate in the tanks and influence the number of deaths during acclimatisation. The especially high mortality rate during acclimatisation of the "Madura 12h" delivery probably cannot be explained by water quality or treatment alone. The authors believe that the number of deaths during the acclimatisation process is largely influenced by the treatment the fish receive during transport and unpacking prior to the acclimatisation process.

Dead on arrival at the central station

Mortality rates at this stage ranged from 0.4–5.5% (Fig. 2). The latter value was observed in the "Madura 13h" delivery and was the result of problems during packing at the Goris branch station. The packing process was stopped when packed fish were dying. The fish were then unpacked and transferred to the acclimatisation system until later, when packing resumed.

In all deliveries but "Madura 13h", the mortality rate was no greater than 1.2%, a relatively small percentage. Although no correlation between the duration of stay in the bags and the number of deaths was found, this seemed to be the commanding negative influence on survival at this stage. Obviously, handling during packing played a role too, as it appeared to have led to the high mortality rate in the "Madura 13h" delivery. Generally we assumed that the stress caused by transport and treatment before arrival at the central station influenced survival at the subsequent stages of processing. Iversen et al. (1998) found that stress from catch and transport of Atlantic salmon resulted in longer times needed to recover — more than 48 hours in some cases. Carmichael (1984) found even longer recovery periods — 96 hours — for *Micropterus salmoides* (largemouth bass, a freshwater species), where the corticosteroid level was elevated in response to the influence of stressors. Although those investigations were made on temperate species, the observations seem to be similar to the stress responses found in coral reef fish. For example, Grutter and Pankhurst (2000) found elevated plasma cortisol levels in *Hemigymnus melapterus* (blackedge thicklip wrasse) as a response to capture and handling. The levels decreased only after 2.5 months of observation in the laboratory, but they still did not reach the levels measured in freshly captured fish. This kind of stress response suggests that wild fish may never acclimate completely to life in captivity.

Death during acclimatisation in the central station

Among the six deliveries, only 0–2% died during the acclimatisation process at the Denpasar central station, substantially less than the mortality rate incurred during the same process at the Goris branch station (Fig. 2). The reasons for the difference were the better equipment, arrangement of tanks and organization of work, and stricter control of handling in the central station. Although water quality in the acclimatisation tanks at the central station was poorer than the water quality found in the tanks at the branch station, the better handling of fish (including unpacking with caution and separating the fish by species to avoid interspecies competition before introducing them to the tanks) seemed to have resulted in lower mortality rates at this stage. It must also be kept in mind that at this point in the processing, the weakest fish had already died.

Death in the stock system at the central station

Most of the DAA died during their stay in the stock system (49–79% of total DAA). Mortalities at this stage accounted for 6–17% of total mortalities (Fig. 2). The highest rate, 17%, occurred in the "Madura 13h" delivery. This may be explained by the especially stressful processing of this delivery, as described above.

All the water quality parameters in the holding tanks, with the exception of salinity, were observed to lie generally with the acceptable ranges cited above. The same was true with respect to the acceptable ranges given in the Export Facilities Supplementary Guidance by the Marine Aquarium Council (2001), which has been written to assist exporters seeking to be certified:

- pH: 7.8–8.5
- free ammonia: up to 0.001 mg L^{-1}
- nitrite: up to 0.125 mg L^{-1}

Salinity was intentionally lowered in the stock system to a level of 26–27‰ for the purpose of parasite prevention — a common treatment recommended by aquarium experts (Bassleer 2000; Baensch and Debelius 1997). This treatment is a stress-causing factor, but since the period of the stay in the stock system is normally a week or less, it should not be a death-causing factor. Rather, its positive influence should outweigh its negative one.

Among the various causes of death observed in the stock system, it was found that bacterial and parasitic infections dominated (Table 2), and that their influence increased with the duration of the stay. Death by diseases caused by bacteria and parasites can be explained by the suppressed immune response of fish caused by chronically elevated cortisol levels induced by handling stress (Grutter and Pankhurst 2000). Fish that are already weakened by the influence of stressors and the resulting stress response cannot resist bacterial and parasitic infections (Barton and Iwama 1991). Even the daily freshwater baths typically given to fish in stock systems cannot prevent the spread of these diseases, but rather, may contribute as an additional stressor to the elevated cortisol levels. In general, it appears that no single factor, including water quality, was the primary death-causing factor for any of the species kept in the stock system. Rather, there were several stress-causing factors that resulted in cumulative adverse effects on the fish, ultimately overwhelming the resistance of the fish to diseases and death (Barton and Iwama 1991).

Conclusions and recommendations

It seems reasonable to conclude that the mortality rates observed in this study, ranging from 10–40%, were unacceptably high. These losses occurred despite the advanced equipment and handling used in the export facility. The high variability in mortalities and injuries among the six observed deliveries indicates that the quality of treatment and handling was quite variable, and suggests that improving consistency in treatment and handling could yield positive results. The large differences in the mortality rates of the first two deliveries from Madura compared to those that followed — after new handling instructions were given to the supplier — indicate that improved handling methods can reduce post-harvest mortality significantly. Clearly, stricter quality control for treatment (including water quality) and handling at the different stages of processing in the branch stations is necessary. The authors provided detailed recommendations to the company's management on possible improvements that could be made at each of the different processing stages.

Although the export company cannot directly control handling during fishing and transport to branch stations by outsiders, training suppliers would undoubtedly result in improvements and is greatly needed. Also urgently needed is a change in the way fish are captured, that is, a move from cyanide-caught to net-caught fish. Rubec et al. (2000) cite an importer of marine fish in the US who experienced a difference of 20% in mortality rates of cyanide-caught fish (greater than 30%) and net-caught fish (less than 10%) from the Philippines. This anecdote points to the reduced resistance to stress of cyanide-caught fish and shows that post-harvest mortality can be significantly lowered just by the use of proper catching methods. Fish that are exposed to cyanide during capture are even more susceptible to stress and show a reduced adaptability (Hanawa 1998). Diseases caused by bacteria and parasites play an important role, especially in the stock system. The findings in this study indicate that even slight improvements in treatment, water quality and handling would be acceptable.

Mortalities observed in this study proved to be highly species dependent. During all six deliveries, 120 species of fish were examined in total. Unfortunately none of the species occurred in all six deliveries and only two species were found in five of the six deliveries. Seven species occurred in four deliveries and twenty species occurred in three deliveries. Deliveries differed substantially in their species composition. The number of individual fish among deliveries also varied greatly, which complicated statistical analysis of species-dependent mortality. In any case, further research is urgently needed in order to identify species not suitable for handling and treatment in the chain of custody. It was observed in this study that the export company did not meet, for a large number of species, the standard for certification established by the Marine Aquarium Council on DOA and DAA (up to 1% each). It was noticed in the course of the study that species were being traded that are known by hobbyists to be difficult to maintain because they have specialised food requirements that are not readily available for home aquaria (e.g. coral polyps). This is consistent with the statement by Sadovy (2002) that 40% of traded species may not be suitable for the average aquarist.

Obviously, further incentives must be put in place in order to reduce mortality. This might be accomplished through the certification scheme being established by the Marine Aquarium Council (certified fish still make up only a small part of the trade). But in any case it will only succeed if buyers insist on better quality products, even if it comes at a higher price. For a business, the certification process requires significant investment, both in equipment and for the certification itself. The prospective benefits to the business of better sales and higher prices for certified products may or may not be sufficient to convince exporters to reduce mortality rates.

In developing countries such as Indonesia, a more detailed guide to assist businesses seeking certification is needed. It should include a step-by-step approach for all treatment and handling procedures, giving detailed instructions on how to meet the standards (such a guide is, in fact, already under development by the Marine Aquarium Council in Indonesia). A certification standard that has a slightly increased DOA and DAA allowance (5%) for a certain transitional period might be the right approach to win over companies for certification, at least in regions where fishing with cyanide is still common and difficult to control.

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Monitoring the chain of custody to reduce delayed mortality of net-caught fish in the aquarium trade

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Abstract

Information obtained from hobby magazines and from informants in the aquarium trade during the mid-1980s indicated that marine aquarium fish had high acute mortality (50%) on the reef due to capture with cyanide, and had 30% mortality on average at each step of the chain of custody — from the village level, through export facilities, to import facilities, and to retailers in North America. More recent data show there is some reduction, although there continues to be high rates of mortality in the marine aquarium trade. The scientific literature also demonstrates that fish experience cumulative stress from being netted, bagged, crowded, and exposed to changes in pH, temperature, salinity, dissolved oxygen, light, and from the accumulation of ammonium ion in the bags (which becomes toxic un-ionised ammonia when the bags are opened). It is believed that with better capture methods (e.g. nets), as well as better handling and shipping practices, it is possible to reduce the mortality at each step of the chain of custody.

It is difficult to obtain accurate marine fish mortality information regarding cyanide-caught fish because those involved fear regulation and/or prosecution for dealing in fish captured by illegal means. Research is needed (with marine fishes held in sealed plastic bags) to determine the range of environmental conditions encountered during transport from exporting to importing countries. Research with freshwater fishes has been successful in prolonging survival in shipping bags by adding chemical additives to inhibit the proliferation of bacteria, neutralize excreted ammonia, buffer pH, and by sedating the fish to reduce their metabolism. Similar research is needed with marine aquarium fish. We hope to demonstrate that with better post-harvest care and handling it is possible to markedly reduce mortality rates of marine ornamental fish during collection and transport.

Introduction

Plastic bags were first used by tropical fish importers to package aquarium fish for transport by air and/or in motorized vehicles in the early 1950s (Miller 1956). Marine aquarium fish were exported by Earl Kennedy from the Philippines in plastic bags starting in 1958 (Robinson 1985). In 1962, Kennedy noticed greater mortalities of marine aquarium fish in his export facility associated with fish obtained from collectors on Lubang Island, south of Manila. He learned that the fish were being collected with sodium cyanide. The marine aquarium trade expanded in the 1970s, fuelled by an abundant supply of cheap fish caught with cyanide. Kennedy left the trade in disgust after he accompanied air shipments and witnessed high mortalities of the fish after their arrival in the US. Dempster and Donaldson (1974), at the Steinhart Aquarium, conducted histological studies during the mid-1960s on marine fish obtained from California waters that were experimentally exposed to sodium cyanide. They found damage to internal organs such as the liver, kidney, spleen and brain. The tissue damage matched that found in marine aquarium fish imported from the Philippines.

Rubec (1986, 1987a) summarized information from various aquarium hobby magazines and from sources in the industry concerning mortality rates for marine aquarium fish in the aquarium trade. It was estimated that 50% of the fish targeted with cyanide died from acute doses on the reef, and that there was on average 30% delayed mortality at each step of the chain of custody. It was estimated that the cumulative mortality through the four steps of the chain of custody (from villages, to export, import, and then to retail facilities) was greater than 80%, if one excluded the acute mortality on the reef (Rubec 1987b). Including the mortality on the reef, the cumulative mortality from reef to retailers was estimated to be greater than 90% (Rubec and Soundararajan 1991). The papers summarized evidence showing that delayed mortalities

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were associated with cellular damage and physiological impairments resulting from exposure to cyanide (Rubec 1986, 1987a).

However, there are those in the aquarium trade who have maintained that the problem is not cyanide, but that it is all "stress, stress, stress" (Goldstein 1997). Goldstein cited a scientific study by Hall and Bellwood (1995) in which damselfish were experimentally exposed to 10 milligrams per litre (mg L^{-1}) cyanide for 90 seconds. He asserted that high mortalities were associated with stress and that the highest mortalities were associated with fish that were both stressed and starved. He stated that there was no evidence that anaesthetic doses of cyanide caused either gut epithelial changes or more mortality than occurred with net-caught fish. Another assertion in Goldstein's (1997) magazine article was that, based on the evidence to date, net collecting did not deliver healthier fish than collecting with cyanide. No evidence was presented. Rubec et al. (2001) discussed mortalities in the aquarium trade and acknowledged that high delayed mortalities of marine fish were probably associated with a variety of factors, including cyanide, stress, ammonia, oxygen depletion, disease, and starvation. It is necessary to consider all factors influencing the fish in order to reduce mortalities occurring in the aquarium trade.

There are many factors that lead to mortalities of marine aquarium fishes, including physical damage and the use of chemicals such as sodium cyanide during collection, inferior water quality, poor handling, disease, and stress at all stages during collection and transport (Wood 2001; Wabnitz et al. 2003). Sadovy and Vincent (2002) stated that mortality levels in both the live food and live aquarium fish trades range from a few per cent to 80% or more for cyanide-caught fish and/or where poor capture, handling and maintenance practices produce stressed animals. The source of the mortality, however, is not always clear.

The problems that must be overcome for the successful transportation of live fish are many and diverse (Norris et al. 1960; Fry and Norris 1962). The primary problem arises from the water's low capacity for oxygen, together with its low capability to dissipate the end products of fish metabolism. The secondary problem is that of handling. In delicate species, abrasion needs only to remove the mucus from a fraction of the area of the skin in order to rob the fish of essential protection from osmotic stress. In addition, many fish are so stimulated by handling that they readily accumulate dangerous levels of lactic acid in their blood. Excessive changes in temperature are also deleterious.

Scientific studies to determine factors causing mortality

Hanawa et al. (1989) studied the response of humbug damselfish (*Dascyllus aruanus*) to cyanide. Groups of 10 humbug damselfish were dipped into several concentrations (25 or 50 mg L^{-1}) of cyanide ion (CN^-) for either 10, 60 or 120 seconds (s); mortality was measured within 96 hours. Test damselfish exhibited no mortality after being dipped in 25 mg L^{-1} CN^- for either 10 s or 60 s. There was 60% mortality after exposure to 25 mg L^{-1} CN^- for 120 s. Likewise, there was no mortality after exposure to 50 mg L^{-1} for either 10 or 60 s; but 100% mortality occurred within 96 hours (h) after CN^- exposure for 120 s. Under stressed conditions (being bagged) previously non-lethal exposures (50 mg L^{-1} CN^- for 60 s) were 100% lethal. Hence, both stress and cyanide resulted in higher mortality after exposure to CN^- for a shorter time period. There was impairment of oxygen consumption by the liver tissue of test fish documented 2.5 weeks post-exposure. Hanawa et al. (1989) concluded that handling stress in combination with anaesthetic doses of CN^- could in part explain the delayed mortality associated with CN^- use in the tropical fish trade.

Hall and Bellwood (1995) assessed delayed mortalities of groups (16 per group) of damselfish (*Pomacentris coelestis*) exposed to cyanide, stress and starvation, alone and in various combinations, over a 13-day period. With each factor separate, the cyanide-only exposure (which also involved handling) resulted in the highest delayed mortality (37.5%), followed by stress-only (25%) and starvation-only (0%). Among the paired combinations, stress+starvation produced the highest mortality (66.7%). The stress-only condition and the handling control both had 25% mortality, indicating that those conditions were stressful to the fish. The results demonstrated that cyanide influenced the delayed mortality both alone and in combination with the other factors. While starvation-only did not produce mortality during the experimental period, the percent mortalities for cyanide+starvation and stress+starvation indicate the importance of starvation in combination with the other factors.

Concurrent conditions

During shipping, several environmental parameters (pH, dissolved oxygen, carbon dioxide, ammonia, temperature) change concurrently in sealed polyethylene plastic bags (McFarland and Norris 1958; Fry and Norris 1962). This makes it difficult to infer which environmental parameters may have killed the fish. A study by Chow et al. (1994) is the only one that has separately determined levels of each environmental parameter inducing 50% mor-

Table 1. **Per cent survival and per cent mortality of damselfish, *Pomacentrus coelestis*, exposed to cyanide, stress and starvation alone and in various combinations (Hall and Bellwood 1995).**

Treatment	Per cent survival	Per cent mortality
Cyanide-only	62.5	37.5
Stress-only	75.0	25.0
Starvation-only	100.0	0.0
Cyanide + stress	75.0	25.0
Cyanide + starvation	66.7	33.3
Stress + starvation	33.3	66.7
Cyanide + stress + starvation	58.3	41.7
Handling control 2	75.0	25.0
No handling control 1	83.3	16.7

tality over time (median tolerance limits – 48 h LD_{50}) on a marine aquarium fish species, the common clownfish (*Amphiprion ocellaris*). They also monitored changes in the levels of environmental parameters over 48 hours resulting from simulated transport of individual clownfish in sealed plastic bags. The median tolerance limits were 1.35 milli-molar (mM) total ammonia (0.079 mg L^{-1}), 57.22 micromolar (µM) un-ionised ammonia (0.003 mg L^{-1}), pH 5.5, and for temperature the upper limit was 34.46°C and the lower limit 19.49°C. It is of interest to note that environmental conditions monitored in the bags over 48 hours (temperatures near 25°C, pH from 8.45 to 6.97, total dissolved ammonia ≤0.36 mM, and un-ionised ammonia ≤1.9 µM) did not reach the median tolerance limits. Although water quality conditions were not incipiently lethal, some of the clownfish died in the bags. It was not clear how the parameters in combination influenced mortality of the clownfish (40% at 48 hours).

Mortalities through chain of custody

Indonesian exporter

Schmidt and Kunzmann (in this issue) monitored mortalities in shipments of marine aquarium fish obtained from middlemen and collectors at a field station in Goris and transported to a central export facility in Denpasar, on Bali in Indonesia. Large variations in mortality were found between shipments and between species. Total losses per shipment — from the point of delivery at the Goris station to the point of packing for export at the Denpasar facility — ranged from 24–51%. The losses were partitioned into: losses due to injury (wounds on the fish), total dead-on-arrival (DOA), and total dead-after-arrival (DAA). The total DAA was defined to include all of the fish dying during acclimation in the field and central stations (not including living fish with wounds screened out at Goris), including fish dying during transport between the stations and in the holding system in Denpasar. The total mortality rate per shipment ranged from 10–40% (Schmidt and Kunzmann in this issue). Most of the mortalities (50–80% of the DAA) occurred in the stock system in Denpasar. Possible reasons suggested for the post-harvest mortality were: a) physical damage to the fish and/or the use of cyanide (during collection); b) poor handling, diseases and stress (in the facilities); c) inferior water quality during transport and in the tanks; and d) the collection of unsuitable species and/or species life stages (e.g. obligate coral feeders).

It seems likely that most of the DOA and DAA reported by Schmidt and Kunzmann (in this issue) can be attributed to the collection and transport methods used by the collectors and middlemen rather than to the handling practices and water quality at the exporter's field and central facilities. The mortalities attributed by the authors to stress and disease in the exporter's facilities appear to be secondary effects induced by cyanide collection, bad handling, and poor water quality during holding and transport in the field and at the village level. Schmidt and Kunzmann noted that the export company could not control the collection and handling methods used by the collectors and stressed the urgent need to switch the collection method from cyanide to the use of nets.

One of the largest aquarium fish exporters in the Philippines admitted to the senior author that fish mortalities in its facility ranged from 30–40%, resulting in a loss of 250,000 US dollars (USD) in dead fish per year. Vallejo (1997) likewise reported that mortality rates at Philippine export facilities ranged from 30–40%, which is greater than the 10% rate estimated for Sri Lanka by Wood (1985) and the 10–20% rate reported for Puerto Rico by Sadovy (1992). These per cent mortality ranges represent the most frequent rates that occur, rather than the overall range.

Mortalities at import and retail levels

Importers were estimated to experience, on average, 30% mortality of fish imported from the Philippines during the mid-1980s (Rubec 1986; Rubec and Sundararajan 1991). In addition, there were reports during that period of fish being left out on the tarmac by the airlines in mid-winter in the importing countries, which resulted in 100% DOA (Rubec et al. 2001).

Robert Fenner, who worked for a large US pet marketing retail chain in the early 1990s, noted that marine aquarium fish mortalities in the stores varied widely from week to week and between species. The stores had an average cumulative mortality of about 20%. The experience of staff and their ability to provide sufficient care was found to be the critical factor at some stores in terms of lowering losses. He noted that most stores did not keep good records of fish losses, other than of what the trade calls "disputable losses" that occur within a day of arrival (DOA).

Chris Whitelaw, the livestock manager for one of Canada's largest aquarium retail chains (20 stores), has been involved with the purchase and sale of marine aquarium fish for over 15 years (C. Whitelaw, pers. comm. 2004). In the early 1990s, he purchased Philippine marine aquarium fishes from a Toronto-based importer. The former owner of this import facility recently informed Whitelaw that the total DOA plus DAA on shipments of fish he obtained ranged from 30–60%. During the same time period, the stores associated with Whitelaw experienced 20–25% mortality on fishes purchased from this wholesaler. The fish exhibited symptoms believed typical of cyanide poisoning, either wasting away and dying despite feeding ravenously, or refusing to eat and dying suddenly despite decent water quality and no apparent signs of disease. Whitelaw later purchased fish from both local and US-based transshippers, which were believed to be cyanide-caught, and experienced mortalities of 20–30%.

In 1996, Whitelaw (pers. comm. 2004) started to import net-caught fish directly from Philippine exporters who had obtained their fish from collectors trained by either the Haribon Foundation/Ocean Voice International (OVI) or the International Marinelife Alliance (IMA). The fish rarely, if ever, showed signs of cyanide, but they frequently showed signs of starvation and poor handling. After working with these suppliers to determine proper densities of fish per unit volume of water in bags placed in shipping boxes for the 36–48 hour trip, the rate of DOA experienced was less than 5% and the rate of DAA an additional 5–10% of the total number of fish received per shipment. Hence, the total DOA plus DAA with net-caught fish presently ranges from 10–15%.

Heidel and Miller-Morgan (2004) recently conducted veterinary studies at wholesale/import facilities on the west coast of the US on fish imported from Indonesia and the Philippines. The studies involved more than 300 individual fish representing 79 species, and they were conducted within hours of the fishes' arrival. The condition of dead, moribund and healthy fish was assessed through water analyses, necropsies and histological and microbiological analyses. Overall mortality ranged from 0–16%, but in some species mortality rates were as high as 100% (J. Heidel pers. comm. 2004). Aside from mortality, other external signs included disequilibrium, gaping, flared opercula, skin ulcerations, haemorrhages, increased mucus production, gill damage and external protozoa and bacteria. Water quality was not always optimal, and the data indicated that many fish arrived with pre-existing health problems and/or infections. The presumption was that the stress of capture, holding and transport, together with deteriorating water quality and opportunistic or epizootic infections, led to the observed fish losses (Heidel and Miller-Morgan 2004). Although the study is not complete, preliminary results indicate significant water chemistry imbalances, while infectious and parasitic diseases were found to be minimal (J. Heidel pers. comm. 2004).

Three importers of marine aquarium fish near Tampa, Florida revealed in 2004 that the pH of the water in plastic bags received from the Philippines generally ranges from 6.1–6.5 after flight durations exceeding 35 hours. The drop in pH to levels below 6.5 in sealed plastic bags associated with air shipments seems to be a significant source of stress.

It generally takes about five to seven days after the removal of fish from sealed containers for corticosteroid and glucose stress hormone levels to decline to baseline levels (Carmichael et al. 1984a,b). Most importers do not hold the fish in their facilities long enough for this to happen before they ship the fish on to wholesalers or retailers. Most retailers have no experience in acclimating marine fish received from transshippers. Mortality rates of fish received directly from overseas to retail stores are generally higher than mortality rates for fish received from domestic importers or wholesalers (Rubec et al. 2001). Fish shipped for longer time periods over greater distances experience more stress, which may contribute to higher rates of DAA.

Acclimation procedures

Because of the accumulation of ammonium ion (NH_4^+) and the drop in pH in the bags resulting from carbon dioxide excretion by the fish, most exporters and importers use acclimation procedures when removing fish from plastic bags. Prior to 1996, most importers receiving fish from overseas dumped the fish, along with the water from the bags, into plastic bins or other containers. They then dripped clean seawater into the bins to gradually raise the pH and acclimatize the fish to the seawater in their holding systems. The Canadian store manager (Whitelaw) noted that his staff also added Ammolock® to the water in the bins to neutralize the ammonia. Starting in 1996 they transferred the fish more quickly to clean seawater with the pH lowered using hydrochloric acid. Three marine fish importers near Tampa, Florida, acknowledged using carbon dioxide to lower the pH of the seawater. One claimed that he had markedly reduced his mortality rates using this method, compared to earlier methods such as using monobasic sodium phosphate (NaH_2PO_4) or various acids to reduce the pH of the acclimation water. Another stated that his mortalities were reduced by 5% since adopting the new method in 1999. A third importer noted that her DOA+DAA using the carbon dioxide method was, on average, 8%. However, she also acknowledged that with some shipments, all of the damselfish died after arrival. She speculated that this might be because they were collected with too high a concentration of cyanide.

The carbon dioxide method is now in use by some exporters in the Philippines and Indonesia. According to Schmidt (2003), carbon dioxide gas was infused into seawater to lower the pH from 8.3 down to 6.75 to 6.85 at the Goris field station. Once the fish were placed in acclimation tanks containing the low-pH water, the carbon dioxide infusion was stopped. The pH of the water was then allowed to slowly increase (via dissipation of the carbon dioxide to the atmosphere) to a range of 8.1–8.4 over a period of at least three hours. Similar methods were used in the central export facility situated in Denpasar. The pH in the bags on arrival at the Denpasar facility ranged from 6.90–7.55. The pH was slowly raised in the acclimation system to a pH range of 8.0 to 8.2. The fish were then transferred to the holding system where the pH of the seawater ranged from 8.1–8.5.

Reducing mortality with net-caught fish

The mortalities reported for marine aquarium fish shipped in sealed plastic bags through the chain of custody from the villages to export facilities, to overseas import/wholesale facilities, and then to retail stores are too high (Rubec 1986; Rubec and Soundararajan 1991). Rubec et al. (2001) stated that mortalities could be reduced if the fish were captured using nets rather than cyanide, and if better shipping and handling methods were adopted. A feasibility study for the Marine Aquarium Council found that the mortality rates for aquarium fish caught using barrier nets and subject to better handling were reduced from 30% to less than 5% on fish transported from the villages to Manila-based exporters (Rubec and Cruz 2002).

Rubec et al. (2001) noted that a small importer situated in New Jersey, US experienced more than 30% mortality with cyanide-caught fish compared to less than 10% mortality with shipments of net-caught fish imported from the Philippines, when both were properly acclimated. The Canadian importer in Toronto had mortalities of 30–60% associated with cyanide-caught fish, while the livestock manager (Whitelaw) importing net-caught fish from the Philippines experienced 10–15% DOA+DAA. Rubec et al. (2001) suggested that if the cumulative mortality through the chain of custody could be reduced from more than 90% to less than 10%, everyone would make more money. It seems likely that large reductions in mortality rates can be achieved by stopping cyanide fishing and stabilizing environmental conditions by using chemical additives in shipping bags. At present, most exporters do not add any chemicals to the shipping water to stabilize the water quality.

Studies with chemical additives

In the case of ornamental fish produced by means of aquaculture it may be possible to improve the condition of the fish by improving water quality in the ponds through the use of antibiotics and other prophylactic treatments and/or by the addition of food additives such as vitamin C (Lim et al. 2002; Lim et al. 2003). This paper is more concerned about measures that can be taken with marine aquarium fish collected from the wild, such as the use of chemicals that can be added to sealed plastic bags at various points through the chain of custody from the field to retailers.

Buffers

McFarland and Norris (1958) studied changes in the pH of seawater in sealed containers containing California killifish (*Fundulus parvinnus*) to mimic conditions in plastic bags. They found that the pH of the seawater declined rather quickly (most of the decline occurred within the first 8 hours). The low pH and/or the accumulation of dissolved carbon dioxide at low pH values were believed to contribute to 50% mortality as the pH declined to 6.0 over a 50-hour period. They also reported that even though the water contained adequate dissolved oxygen, the fish could not use the oxygen at high carbon dioxide levels because of Bohr and Root effects, which inhibit the ability of the blood to transport oxygen at low pH. The accumulation of carbon dioxide acidified the water, explaining the drop in pH.

McFarland and Norris (1958) found that they could markedly improve water quality conditions and the survival time of the fish kept in sealed containers by adding tris buffer. Tris buffer was found not to be harmful to 25 species of marine fish and four species of freshwater fish. In the control tests lacking buffer mentioned in the previous paragraph, 50% mortality occurred with California killifish (65 g of fish per gallon) in sealed containers as the pH dropped from 7.8 to 6.0. Tests with similar densities of killifish were conducted by adding 10 g per gallon of tris buffer. In the first treatment, the water was buffered to a starting pH of 8.25. The killifish experienced 50% cumulative mortality by the sixth day as the pH fell to 6.7. In the second treatment, the starting pH was 7.8 and the fish experienced 50% mortality after 4.9 days, at a pH of 6.5. The killifish survived much longer with tris buffer than in the control case where the seawater was not buffered. The buffer slowed the rate of pH decline and increased the time to reach 50% mortality.

McFarland and Norris (1958) and Amend et al. (1982) found that tris buffer reduced the rate of decrease in pH in studies involving California killifish and southern platyfish (*Xiphophorus maculatus*) held in sealed containers in comparison to controls lacking buffer. McFarland and Norris (1958) found that adding tris buffer reduced the rate of accumulation of carbon dioxide in comparison to two control groups lacking buffer. The accumulation of carbon dioxide followed the trend to be expected in the presence of a substance capable of buffering the carbon dioxide (by converting it to less toxic bicarbonate ion).

Elimination of ammonia

Two methods are commonly used to control the accumulation of ammonia in transport water: preventing ammonia formation by slowing the metabolism of the fish and removing ammonia after it has been excreted (Bower and Turner 1982). The first method uses sedatives or lowers water temperatures; the second method uses compounds that bind the ammonia, such as ion-exchange resins or zeolites. Clinoptilolite is a naturally occurring mineral that acts as a zeolite (hydrated silicates of aluminium with alkali metals and/or alkaline earth metals) capable of binding with ionised ammonium (NH_4^+) and un-ionised ammonia (NH_3) to remove ammonia from solution in water.

Bower and Turner (1982) demonstrated that clinoptilolite was effective in significantly reducing ammonium ion ($p<0.01$) and un-ionised ammonia ($p<0.05$) concentrations in freshwater during simulated transport of goldfish (*Carassius auratus*) held in sealed polyethylene bags. Although small clinoptilolite particles remove ammonia more effectively than large particles because of their greater surface area, large 2–5 mm diameter particles were recommended because they did not cause the water to become turbid.

Problems have been identified with respect to the removal of ammonia from freshwater with increasing weights of clinoptilolite (Teo et al. 1989, 1994). Higher percent mortalities of guppies (*Poecilia reticulata*) and tiger barbs (*Barbus tetrazona*) occurred at higher densities of clinoptilolite, despite the fact that total ammonia ($NH_3 + NH_4^+$) concentrations in the packing water declined with increasing weights of clinoptilolite. This may have been related to the turbidity caused by fine clinoptilolite particles in the water, which may have clogged the gills of the fish, causing asphyxiation. Currently, the aquarium trade uses larger particles of clinoptilolite placed in plastic mesh bags inside sealed plastic bags during shipping of freshwater fishes to overcome this problem.

Clinoptilolite is not effective in seawater (Turner and Bower 1982). Liquid formulations (e.g. Amquel®/Cloram-X®) need to be evaluated for their ability to bind unionised ammonia in seawater during shipping. However, Amquel® cannot be used in conjunction with tris buffer (Robertson et al. 1987). Apparently, this is because the tris buffer molecule has an amine grouping, which binds to the Amquel. This problem can be overcome by using buffers lacking amines in conjunction with liquid agents that bind ammonia.

Control of bacteria during shipping

Amend et al. (1982) tested various chemicals to assess their ability to retard bacterial growth in plastic bags compared to untreated controls and to test the tolerance of fish to each chemical. There was no mortality associated with neomycin sulfate. It also was the least expensive of the chemicals tested. Neomycin sulfate has also been used in other experiments with freshwater aquarium fish to control bacterial proliferations in shipping bags (Teo et al. 1989, 1994).

Invasive bacteria are responsible for skin and fin infections on marine fish, which frequently occur after handling operations (Colorini and Paperna 1983). Experiments with a marine fish (*Sparus aurata*) and a freshwater fish (*Oreochromis mossambicus*) demonstrated that immersing the fish in 100 mg L^{-1} of nitrofurazone for 6 hours effectively reduced the proliferation of bacteria in the water, prevented bacterial colonization of skin lesions and minimized the possibility of developing a systemic infection. Post-mortem analyses of the fish found that the nitrofurazone was not absorbed internally. Hence, nitrofurazone was found to be suitable for use associated with netting and/or transfers that cause scale loss and minor injuries. It has the advantage that it can be used with biological filters because it does not interfere with gram-positive nitrifying bacteria to any significant extent. Because nitrofurazone is not taken up and retained by the fish it is less likely to induce antibiotic-resistant strains of bacteria than other chemicals. Interviews with several US importers and several exporters in the Philippines indicated that nitrofurazone has been used in the transport and holding of marine aquarium fish.

Anaesthetics/sedation

Anaesthetics have been shown to be effective in lowering metabolic rates by reducing the motor activities of fish, and they may be used to further reduce metabolic waste production (McFarland 1960). The use of anaesthetics in the transport of ornamental fish has not been fully explored (Lim et al. 2003). Anaesthetics may be used to limit the stress responses of fish, but there are conflicting reports on this subject. The sedatives most commonly used by the industry to ship aquarium fish are quinaldine or quinaldine sulfate, and tricaine methane sulfonate (Cole et al. 2001).

A number of experiments using the anaesthetic 2-phenoxyethanol have been conducted with guppies, tiger barbs, and mollies (*Mollenesia sphenops*) — all freshwater fish, either alone or in combination with other factors (Teo et al. 1989, 1994; Kwan et al. 1994). The experiments indicate that 2-phenoxyethanol alone was capable of lowering mortality rates. Associated water quality parameters such as total ammonia and total carbon dioxide were generally not directly lethal. There is some indication that low dissolved oxygen concentrations were lethal to tiger barbs (Teo et al. 1994). The data indicate that the 2-phenoxyethanol reduced the mortality associated with sublethal levels of total ammonia and/or the drop in pH measured during simulated transport experiments with fish in sealed plastic bags (Teo et al. 1989, 1994; Kwan et al. 1994).

Chemical combinations

Tests with 2-phenoxyethanol plus tris buffer resulted in lower percent mortalities than the other paired combinations (clinoptilolite+tris buffer, clinoptilolite+2-phenoxyethanol), both with guppies and with tiger barbs (Teo et al. 1989, 1994). The low percent mortalities with the combination of sedative and buffer were not associated with either lower carbon dioxide or lower total ammonia concentrations compared to the water quality obtained for the two other paired combinations. Highest percent mortalities were associated with the clinoptilolite plus tris buffer combination for both guppies and tiger barbs. In tests using 20 g L^{-1} clinoptilolite and 0.02 M tris buffer with various densities of tiger barbs (40, 60, 80 fish per 3 L of water and 3 L of oxygen gas per bag), the mortality jumped up from 0% at 60 fish per bag to 83.3% at 80 fish per bag (Teo et al. 1994). This was attributed to a low concentration of dissolved oxygen (1 mg L^{-1}) for the test using 80 fish per bag. However, no depletion of dissolved oxygen (20.6 mg L^{-1}) occurred with clinoptilolite plus tris buffer that could explain the associated mortality (11.7%) of guppies at a density of 20 fish per 400 ml of water per bag (Teo et al. 1989).

An analysis of variance (ANOVA) was conducted by Teo et al. (1989) to assess the influences of clinoptilolite, tris buffer and 2-phenoxyethanol alone and in various combinations on water-quality parameters and the mortality of guppies. All three chemical additives added separately or together in paired combinations had significant effects on ammonia concentrations ($p \leq 0.01$). Both 2-phenoxyethanol alone and the interaction term for clinoptilolite*2-phenoxyethanol had significant effects ($p \leq 0.01$) on the dissolved oxygen concentrations in the bags containing guppies (the fish consumed less dissolved oxygen when they were anaesthetised). All three chemical additives together exhibited a significant ($p \leq 0.05$) three-way interaction effect in relation to dissolved oxygen. Both tris buffer alone and 2-phenoxyethanol alone had significant effects ($p \leq 0.01$) on reducing mortality rates of guppies in sealed plastic bags. Clinoptilolite also contributed to a significant ($p \leq 0.05$) reduction in mortality.

Buffer + clinoptilolite + temperature + sedative

In another series of tests by Teo et al. (1989) the density of guppies was varied (40, 50, or 60 fish per bag containing 600 ml of water) at two temperatures (20 and 25°C), with 0.02 molar (M) tris buffer, with or without the presence of 0.22 grams per litre (g L^{-1}) 2-phenoxyethanol. Mortalities were lower in the presence of 2-phenoxyethanol. At higher densities of guppies (50 or 60 fish per bag) the mortality was lower at 25°C than at 20°C with the two factors used together. At a density of 50 fish per bag, the mortality was 2% at 25°C, and 6% at 20°C. At a density of 60 guppies per 600 ml of water, the mortality was 5% at 25°C, and 5.6% at 20°C. The results of these trials showed that with the application of suitable concentrations of tris buffer, clinoptilolite, and 2-phenoxyethanol, it was possible to increase the packing density of the guppies.

The environmental conditions recorded by Teo et al. (1989) at various densities of guppies are summarized in Table 2 (the data in the authors' original table are reorganized here to separate the tests at 20°C from those at 25°C). The data presented are averages for the environmental conditions associated with three bags of fish for each test and control condition.

It is apparent from Table 2 that total dissolved carbon dioxide levels measured and the associated percent mortalities were higher in those tests where 2-phenoxyethanol was not added (Teo et al. 1989). At 20°C and densities of 40 and 60 fish per bag the dissolved oxygen (DO) levels were lower where 2-phenoxyethanol was absent than in those tests where the anaesthetic was present. At 25°C the DO level was higher in the test lacking the anaesthetic (40 fish per bag) in comparison to DO levels where the anaesthetic was present. There also were higher total ammonia concentrations in bags held at 25°C than at 20°C. Total ammonia was higher in two out of three cases where the anaesthetic was absent compared to where the anaesthetic was present along with the buffer and clinoptilolite. At a density of 40 fish per bag, the presence of the anaesthetic lowered the accumulation of ammonia at 20°C ($p<0.05$). At 25°C and a density of 40 guppies per bag the total ammonia concentration was lower with the anaesthetic present than without but the difference was not significant ($p>0.05$). The authors concluded that 2-phenoxyethanol appeared to be needed for packing guppies at 20°C. In preliminary tests, lowering the water temperature below 20°C increased the mortality of guppies (all died at 15°C). Froese (1998) summarized data that indicated tropical fish survive best when water temperatures during shipping match those found in their natural environments (22–30°C).

Discussion

The data obtained from persons involved with importing marine aquarium fish from the Philippines indicated there was a lower mortality associated with net-caught fish than with cyanide-caught fish. Several importers of fish originating from the Philippines have stated that their mortalities declined during the latter part of the 1990s. This may be related to the decline in the prevalence of cyanide in marine aquarium fish monitored by six cyanide detection test (CDT) laboratories run by the IMA (Rubec et al. 2003). The presence of cyanide declined from 43% in 1996 to 8% in 1999, and then increased to 29% in 2000, based on 7703 aquarium fish specimens tested. Other factors such as improvements in filtration systems and changes in acclimation procedures discussed in the present paper may also have influenced mortality rates over this time period.

The water quality associated with holding systems and during transport in plastic bags appears to be very important. Several exporters have informed the senior author that they experienced higher mortality when the seawater used in their facilities was obtained from Manila Bay. Lower mortalities occurred when they obtained their system water at distances further away from Manila. One exporter of net-caught fish obtains seawater transported by tank truck from Subic Bay. This exporter believes that it is important to obtain unpolluted seawater and to maintain good water quality in the facilities.

The scientific literature reviewed herein indicated that fish died in plastic bags, even when water quality conditions were not incipiently lethal. Studies have demonstrated that chemical additives can be used to increase the density of guppies, tiger barbs and mollies shipped in sealed plastic bags

Table 2. Water quality parameters and percent mortalities monitored with guppies held in sealed plastic bags in 600 ml of water, with 20 g clinoptilolite, 0.02 M tris buffer, and 40 to 60 fish per bag, held for 48 hours at either 20°C or 25°C, with or without 2-phenoxyethanol (Teo et al. 1989).

Treatment				After exposure				
Fish density (no. bag^{-1})	Total fish weight (g)	Temperature (°C)	2-phenoxyethanol (g L^{-1})	Carbon dioxide (mg L^{-1})	Total ammonia (mg L^{-1})	pH	Dissolved oxygen (mg L^{-1})	Mortality (%)
40	32.1	20	0.22	542	3.03	7.43	18.0	3.3
40	28.3	20	0.00	748	5.44	7.50	11.0	6.7
50	32.8	20	0.22	579	7.04	7.57	18.0	6.0
60	37.4	20	0.22	234	5.80	7.10	20.3	5.6
60	34.8	20	0.00	841	26.90	7.05	6.3	13.0
40	31.4	25	0.22	497	13.99	7.15	5.9	5.8
40	28.7	25	0.00	681	16.56	7.35	7.1	10.0
50	34.4	25	0.22	588	14.25	7.26	6.6	2.0
60	36.3	25	0.22	494	14.70	7.11	10.3	5.0

(Teo et al. 1989, 1994; Kwan et al. 1994). However, there appeared to be an upper limit to the density of fish that could survive together in the shipping bags. In the case previously discussed involving paired combinations of clinoptilolite and tris buffer (Teo et al. 1994) one might attribute the tiger barb mortality (83.3%) to the clinoptilolite becoming saturated with ammonia, since the total ammonia concentration was high (27.1 mg L^{-1}) at the highest fish density (80 fish per bag). However, in the case of guppies using the same combination of chemical additives, the total ammonia concentration was low (3.7 mg L^{-1}) and the dissolved oxygen concentration was high (20.6 mg L^{-1}), yet the mortality (11.7%) was relatively high (Teo et al. 1989). Other factors such as physiological stress due to crowding may account for the observed mortalities. This may explain why mortalities increased markedly at the highest fish densities in the bags.

Fish experience cumulative stress from being netted, bagged, crowded, and exposed to changes in pH, temperature, salinity, dissolved oxygen, light, and from the accumulation of ammonium ion in the bags, which becomes toxic un-ionised ammonia when the bags are opened (Rubec et al. 2001). The main finding of experiments with freshwater fish using chemical additives in various combinations was that 2-phenoxyethanol in combination with tris buffer had a marked influence in reducing mortality rates of guppies, tiger barbs, and mollies (Teo et al. 1989, 1994; Kwan et al. 1994). No explanation for how 2-phenoxyethanol reduced the mortality rates was provided. Experiments with rainbow trout (*Oncoryhynchus mykiss*) found that 2-phenoxyethanol reduced the excretion of cortisol in the blood, which is commonly associated with physiological stress responses (Iwama et al. 1989).

Study of chemical additives for shipping marine fish

No experiments have been published involving the use of more than one chemical additive in plastic bags used to ship tropical marine aquarium fishes. There is a need to conduct studies on marine aquarium fish similar to those conducted on freshwater fish.

Fish collectors travel long distances by boat to find reefs that have not been devastated by the use of cyanide and other types of destructive fishing such as explosives (Rubec 1986, Rubec 1988; Rubec et al. 2003, Cervino et al. 2003). We plan to study post-harvest handling and transport practices from the moment the fish are captured using nets and during their transport to the villages, as well as how they are held prior to shipment to export facilities in Manila. We plan to study this closely because much of the mortality through the chain of custody appears to be related to the collection and transport methods used by collectors and middlemen. Where it is possible, we will compare mortalities for net-caught fish with those for cyanide-caught fish handled and transported in a similar manner.

Many fish are held in plastic bags at the village level, adding to post-harvest stress (Baquero 1995). Alternatives to this practice include the use of floating cages, submerged net-bags, and regional holding facilities (Rubec and Cruz 2002). We intend to test these alternatives and to document fish mortality rates under each of them.

After determining mortality rates, by species, associated with conventional shipping methods lacking chemical additives, experiments will be conducted to test the effects of various chemicals added to the shipping bags. The chemical additives will be evaluated by making shipments from the villages through the chain of custody to retailers in the US. Plastic bags with one-quarter seawater and three-quarters oxygen gas (by volume), along with chemical additives, will be used for export of the fish. The numbers of DOA and DAA will be monitored at each step of the chain.

We plan to first bag fish and place them in shipping boxes and hold them for 48 hours with and without chemical additives at a Philippine export facility. We plan to evaluate the chemicals alone and in various combinations in a manner similar to the research by Teo et al. (1989, 1994). The concentrations of needed additives will first be determined from the published literature. After that, we plan to vary the concentrations of some chemicals to determine optimal concentrations that are safe for use with the fish in the bags. Chemical additives will be used to stabilize the pH, to neutralize un-ionised ammonia as it is excreted and to stop the proliferation of bacteria in the shipping bags. This will allow us to choose the best chemical combinations and optimal concentrations of each chemical additive.

By stabilizing water quality conditions in the plastic bags during transport, we hope to eliminate or markedly reduce shipping stress and secondary effects (like disease) on the fish caused by stress-inducing factors such as rough handling, ammonia, and other adverse water quality conditions. The scientific literature indicates that this is possible. While there may be some companies using some of these techniques, they are not commonly applied to the shipping of marine aquarium fish. We believe that mortality rates of less than 1% at each step of the chain may be achieved. This may allow the exporters to pay the collectors more for net-caught fish and increase the profitability of marine aquarium fish enterprises through the chain of custody from reefs to retailers. This does not imply that the prices for net-caught fish being exported need to be higher. We believe that net-caught fish can be exported at prices competitive with those of exporters selling cyanide-caught fish.

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Integrating marine conservation and sustainable development: Community-based aquaculture of marine aquarium fish

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Introduction

Conservation of marine biodiversity depends on the successful resolution of development challenges. Exploitation of marine resources increases and poverty is exacerbated as human populations grow. Nowhere is this clearer than in the subsistence fishing communities of tropical Indo-Pacific countries. Increasing demand for marine resources and the gap between supply and demand have led to the rapid depletion of conventional food fisheries (Pauly 1997). Poverty, a lack of alternative livelihoods and, in some cases, greed, drive fishers to exploit stocks to the point of growth and recruitment overfishing (Hall 1999). Fishing continues despite consequent declines in catch because fishing is typically the occupation of last resort.

Subsistence fishers find themselves in a downward spiral of resource degradation and increasing poverty as overfishing develops. These fishers tend to be socially and politically marginalised because of rural remoteness, low levels of education, and large numbers of dependants in each family. Their communities often lack the organisational and decision-making skills that are necessary for effective resource management. As overexploitation continues, effort shifts to species that previously supported limited levels of exploitation (Orensanz et al. 1998; McManus et al. 2000). Such shifts are problematic where they involve heavy exploitation of species poorly suited to fishing pressure, such as those with low growth rates or low fecundity (e.g. seahorses; Lourie et al. 1999). The costs of overfishing are thus two fold: marine biodiversity decreases as fishers sequentially exhaust resources and destroy the resource base; and poverty and marginalisation increase.

Alternatives to fishing as a primary livelihood are central to meeting development goals in fishing communities. However, alternative livelihoods cannot be considered in isolation if conservation as well as development goals are to be met. The high demand for marine resources suggests that as supply diminishes, prices are likely to rise. Eventually, fishery-derived income may become sufficiently high to entice fishers engaged in alternative livelihoods to re-enter the fishery. High prices will motivate such re-entry even if the resources are substantially depleted. Thus, the value of alternative livelihoods in promoting the conservation of biodiversity must be evaluated carefully.

Alternatives to fishing that actively reduce the demand for wild-caught marine resources are more likely to meet conservation goals than alternatives that only generate income. Marine aquaculture (mariculture) is a livelihood alternative to fishing with great potential to integrate conservation and sustainable development goals in developing countries. Aquaculture's conservation advantage over other alternative livelihoods is that it can both provide sustainable income and address ongoing market demand by creating high value alternatives to wild-caught animals.

Conservation and community-based aquaculture of marine ornamental fish

Marine ornamental fish, that is, the colourful fish collected for the marine aquarium trade, present an excellent opportunity for community-based, conservation-focused aquaculture initiatives in developing countries. Community-based aquaculture that has the effect of reducing exploitation of wild populations of marine ornamental fish (MOF) provides a number of direct conservation benefits, as discussed below.

First, most MOF come from coral reefs, and the high exploitation rates for some species have caused concern over their conservation status (Edwards and Shepherd 1992; Hawkins et al. 2000; Tissot and Hallanger 2003). Current estimates indicate that between 10 and 35 million fish are traded as marine ornamentals annually (Baquero 1999; Wood 2001), with more than a thousand species

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involved (Wood 2001; Wabnitz et al. 2003). However, the large number of species traded masks the regional impact of the marine ornamental trade on highly sought-after species.

The tropical Indo-Pacific region, with its high marine biodiversity, is the major supply centre for MOF (Baquero 1999; Wood 2001). Indonesia and the Philippines, for example, supply more than 85% of the global trade (Baquero 1999; Wood 2001). The bulk of the trade comprises a relatively small number of species, with the top 10 fish species traded accounting for approximately 36% of the overall volume traded (Wabnitz et al. 2003). In Hawaii, for example, 11 species accounted for 90% of the marine aquarium fish collected in 1995, and declines have been observed in the sizes of populations of the more highly sought after species (Tissot and Hallanger 2003).

Size selectivity and sex selectivity in the marine ornamentals trade are also conservation concerns. For many angelfish species, for example, juveniles are more desirable than adults due to their coloration patterns and their more suitable size for home aquaria. As a result, they are a primary target of the fishery. This practice is of concern as it may eventually lead to recruitment overfishing (Pauly 1988). Sex-selective fishing pressure in species that display sexual dichromatism/dimorphism is also of concern as it may lead to declines in reproductive output. By reducing the exploitation of vulnerable marine ornamental fish species, aquaculture could relieve much of the conservation concern over their status in the wild.

Second, community-based culturing of MOF promotes ecosystem stewardship. Environmental degradation poses threats to MOF as their coral reef habitats are among the most threatened in the world as a result of destructive fishing methods, agricultural runoff, coastal urbanisation and myriad other threats (Norse 1993; Bryant et al. 1998). Most MOF come from oligotrophic coral reef waters and only thrive when water quality is high. Culturing them also requires high water quality (Job et al. 1997). Community-based aquaculture will, therefore, place a measurable premium on maintaining high coastal water quality, as deteriorating water quality will be directly detrimental to aquaculture efforts. Linking successful marine ornamental aquaculture with the prevention of water quality deterioration and ecosystem damage will achieve far-reaching benefits in coastal communities.

Third, impacts on marine productivity may be minimised by culturing marine ornamentals. The majority of MOF are herbivorous or planktivorous. In contrast to piscivores, the dietary requirements for herbivorous and planktivorous species are such that culture operations for the latter have more potential for sustainability, and will lead to less pressure on feed fish (Naylor et al. 2000). Aquaculture of high value food fish species fed on piscivorous diets results in net costs to the marine food webs supporting this culturing, as the amount of fish consumed as feed substantially outweighs the amount produced in cultured biomass (Naylor et al. 2000). There are, for example, concerns over the use of so-called "trash fish" for grouper aquaculture in the region. MOF aquaculture, in comparison, would be far more ecologically sustainable.

Fourth, community-based culturing of marine ornamentals promotes global conservation objectives by respecting the spirit of the Convention on Biological Diversity (CBD). The CBD recognises that the commercial exploitation of valuable biological resources must benefit source countries and the communities that depend on these resources. In the absence of such benefits, there is little incentive for source communities to conserve their biodiversity in the face of overwhelming poverty. Moreover, resource users (e.g. fishers) will continue to exploit their biological resources in the absence of alternative livelihoods and in the presence of continued market demand. Community-based marine ornamental aquaculture provides an opportunity to culture species within their natural distributions, particularly in the Indo-Pacific region where the greatest biodiversity of MOF is found.

Fifth, aquaculture of marine ornamental fish may be more effective in ultimately conserving marine resources than regulations that restrict exploitation. Regulations are likely to be imposed if the trade is not made sustainable. Legal restrictions on the collection of MOF in some areas have already been imposed by management agencies within source countries such as Australia, Indonesia and the Philippines. Moreover, the United States, the single largest market for marine ornamentals, has considered restrictions at the import end of the trade (CRTF 2000). In the absence of alternative livelihoods, restrictions on the collection or trade of target species often simply lead to the targeting of new species that are no better able to withstand exploitation. This is exacerbated by the marine ornamentals industry encouraging new and different species to enter the trade, and a lack of understanding of the biology and abundance of many of the species being exploited (e.g. Kolm and Berglund 2003). Community-based aquaculture would break the vicious cycle of shifting from resource to resource, as well as meet market demand.

Sustainable development and community-based marine ornamental aquaculture

Community-based marine ornamental fish aquaculture must be economically viable if it is to contribute to the sustainable development of coastal communities. The likelihood of MOF culturing being commercially viable is high. The global trade in marine ornamentals is estimated to be worth between 200 and 330 million US dollars (USD) per year at the retail level (Baquero 1999; Wabnitz et al. 2003). By unit weight, MOF are worth on average USD 247 kg^{-1}, a value substantially greater than that for fish species exploited in capture fisheries or aquaculture generally (Table 1). The value of the trade is especially great in some countries. In the Maldives, for example, MOF were worth almost USD 500 kg^{-1} in 2000 (Wabnitz et al. 2003). As supplies of marine ornamentals become ever more constrained due to high exploitation rates and the use of destructive fishing techniques, the market value for cultured species can only increase with time, with greater benefits to those communities producing cultured individuals.

Marine ornamental fish are valuable at young ages and small sizes, which further increases the economic potential of MOF aquaculture. Juveniles and subadults are preferred for many species (Wabnitz et al. 2003). Juvenile blue tangs (*Paracanthurus hepatus*), for example, are highly sought after even at sizes as small as 2.5 to 5 cm in (total) length, and can command between USD 2.50 and 4.00 each at this size (freight-on-board (FOB) prices from Indonesia, S. Job unpublished data). Juveniles of species such at the pomacanthids (angelfish) can be even more valuable (USD 12–14 per fish FOB from Bali). The high value at young age is a key advantage of marine ornamentals aquaculture as the time taken to reach market size is short in comparison to most food fish species. Many MOF species reach market size within 4 to 6 months. This reduces the risk inherent in any community-based aquaculture initiative from events such as storms, theft, vandalism, and so forth. Furthermore, the short time to market facilitates batch culturing by local communities. This allows culturing effort to be intensified during those times of the year when livelihoods such as wild capture fishing are less productive.

The small size of most marine ornamental fish species increases the feasibility of developing small-scale aquaculture operations in coastal communities. Effective integration of all levels of the culturing operation, from hatchery production to grow-out to marketing, is possible even in small-scale MOF operations as space and infrastructure requirements are much smaller than for most high value food fish species. The costs involved in establishing and operating aquarium fish aquaculture operations are, therefore, also substantially smaller. The reduced space, infrastructure and cost requirements facilitate local communities engaging in marine aquarium fish aquaculture as an alternative livelihood.

Challenges

The first key challenge is to develop aquaculture techniques that are suitable for coastal communities in the region. Current aquaculture production of MOF is largely based in developed countries such as the United States and the United Kingdom. The use of expensive high-technology methods and equipment in these operations restricts their applicability to fishing communities in tropical Indo-Pacific nations. The focus in the region should be on developing techniques that meet the needs of

Table 1. Global annual volumes landed, total annual economic value and price per kilogram for the capture fisheries, aquaculture and ornamental fish sectors. Data sources and calculations indicated by footnote. Marine capture and aquaculture values are based on prices received by fishers and fish farmers. Marine ornamentals values are based on source country export prices (FOB).

Sector	Volume landed (metric tons)	Total value (million USD)	Unit value (USD kg^{-1})
Capture fisheries	93,021,000[2]	80,123[2]	0.86
Aquaculture	33,213,429[2]	48,229[2]	1.46
Marine ornamental fish	80[3]	20[4]	246.88

2. Estimates for capture fisheries and aquaculture are based on United Nations FAO data averaged from 1996 to 2002, and include all aquatic animals. Source: http://www.fao.org
3. The landings estimates of 80 metric tons (mt) and 12.5 million fish are based on Baquero's (1999) ranges of 60 to 100 mt and 10 to 15 million fish; these correspond to an average weight of 6.4 grams $fish^{-1}$.
4. The mean price per fish was estimated from data presented in Wood (2001) as USD 1.58 $fish^{-1}$. This was multiplied by the number of fish traded (12.5 million fish) to obtain an estimate of total value.

local fishing communities and that address their constraints. The use of high-technology methods in more developed countries does not imply that such techniques are absolutely necessary. Indeed, much of the need for high-technology equipment is a result of culturing tropical coral reef fish in non-tropical locations. Adverse climatic conditions in these places and distance from clean seawater necessitate the use of more advanced equipment. Coastal communities in the region, in contrast, have favourable climatic conditions for much of the year and have access to high quality seawater in many places. With the development of suitable techniques, MOF aquaculture could provide fishers in the region with a much-needed alternative livelihood option.

The second challenge for developing countries is to identify species that are economically viable in their circumstances. The value of the various aquarium fish species varies from country to country as a result of factors such as differences in air-freight costs to the major markets, perceived quality of fish and species diversity and abundance. For example, fish from countries with more expensive freight costs (and generally also more limited air transport links) may have to be sold at lower prices to remain competitive with other countries that export the same species but have lower transport costs (everything else being equal). Thus, the economic viability of culturing various species may vary from country to country. Countries with higher freight costs, for example, may have to focus largely on high value species (Bell and Gervis 1999), while countries with lower freight costs may be able to viably produce a broader range of species of moderate to high value.

Species that are of high conservation concern should also be a priority focus as a complementary mechanism to restrictions on collection and/or trade. This is sensible from an economic viability perspective, as species that are of conservation concern are likely to be those for which overexploitation has led to reduced supply or that are naturally rare. Such species frequently command high prices. Furthermore, such species are more likely to come under trade restrictions and/or monitoring (e.g. seahorses), which may further restrict supply of wild-caught animals. Judicious species selection is key to establishing an economically and ecologically sustainable marine ornamental fish aquaculture industry in the region.

The third challenge is to ensure that participation in culturing activities is open to fishers rather than restricted to local elites. This is challenging as fishers are often among the most marginalised within already marginalised communities. They seldom own land or have access to capital or other resources that would facilitate participation in culturing activities. Community-based culturing initiatives must be designed to facilitate the fishers' involvement by developing protocols that accommodate the constraints within which they function. Technical training, the development of village-based cooperatives, and creative start-up support may be necessary to facilitate the shift of fishers to aquaculture.

The fourth challenge is to restructure the aquarium fish trade in the region to ensure the equitable distribution of benefits derived from culturing. In developed countries such as Australia and the US, aquarium fish collectors generally export their fish themselves or, at worst, supply fish directly to exporters or in-country wholesalers. In contrast, the aquarium trade in most developing countries in the region consists of multiple levels, each level taking a share of the profit (Wood 2001). Typically, fishers receive the smallest profit share, even considering their lower costs and cost of living. Such whittling away of profits by each level reduces the value of each fish to the fisher. Unless this imbalance is addressed, fishers and aquaculturists will remain impoverished. The development of village-based co-operatives may facilitate fishers and aquaculturists obtaining fairer prices for their fish (Rubec et al. 2001). Such cooperatives for fishers are already being developed in a few areas in the region, and the development of similar initiatives amongst aquaculturists should be encouraged and facilitated as the industry develops.

Future directions

Marine ornamental fish aquaculture holds great promise as an alternative livelihood option for fishers in the region. Full-cycle aquaculture currently accounts for only approximately 1 per cent of the global trade in marine aquarium fish (Wood 2001). Approximately forty species are routinely produced commercially. These species are primarily anemonefish, dottybacks, gobies and seahorses. A broader range of species has been bred by both commercial facilities and research institutions, but they are not routinely produced yet (e.g. Job et al. 1997; Job et al. 2002). Species that are produced commercially almost invariably are demersal egg layers or mouth/pouch brooders, have relatively large larvae, and can be bred in small tanks.

Techniques have, however, recently been developed for a number of pelagic spawning species with small larvae, such as the angelfish. The flame angelfish, *Centropyge loriculus*, for example, has recently been produced commercially in Hawaii (Baensch 2002; Baensch 2003). This species has long been one of the holy grails of MOF aquaculture due to its high value and high demand. The successful production of a copepod species as the first food has enabled key breakthroughs in the rearing of this and other angelfish species. Provision of an appropriate first food has long been a major constraint in the aquaculture of MOF species (e.g. Nagano et al. 2000). The recent success with angelfish species is exciting, as the same techniques should allow a broad range of hitherto difficult or "impossible" species to be produced commercially.

The development of a viable marine ornamental fish aquaculture industry in the region needs to be encouraged. Most of the current full-cycle commercial production is based in developed countries outside the region. Existing efforts within the region have focused primarily on collecting post-larval coral reef fish from the wild and then rearing them to market size (Hair and Doherty 2003; Durville et al. 2003). Full-cycle aquaculture production within the region would have some significant competitive advantages compared to countries such as the US and UK. Almost all the costs involved in full-cycle MOF aquaculture are substantially lower in the region. Furthermore, the ideal climatic conditions and access to clean tropical seawater makes the use of low-cost extensive techniques possible (Rubec et al. 2001). The most significant disadvantages are the comparatively high transport costs to the major markets (Bell and Gervis 1999), and the high cost of imported materials and equipment. The high value of most aquarium fish species and the presence of existing trade networks, however, offset the high cost of transport and imported materials. Full-cycle aquaculture would complement techniques based on the collection of post-larval fish by providing a reliable production base. Developing a viable MOF aquaculture industry in the region will promote the conservation of marine biodiversity while facilitating sustainable development in coastal communities.

Tank-bred aquarium fish are in high demand by hobbyists in the major markets. Tank-bred marine aquarium fish in the United States, for example, currently command prices 25% higher than those for equivalent wild-caught fish (S. Job and J. Meeuwig unpublished data). This is primarily a result of successful long-term efforts by commercial producers to promote tank-bred fish as both "conservation-friendly" and better suited to the aquarium environment than wild-caught fish. Early challenges with poor colouration and physical anomalies have been overcome through the development of better culturing techniques. As a result, tank-bred fish are now generally recognised to be of superior quality to wild-caught fish. Increased awareness of coral reef degradation issues amongst hobbyists will continue to ensure that tank-bred fish remain in high demand and command a premium price.

Preventing overexploitation remains a central issue in global coral reef conservation efforts. The presence of high numbers of fishers in the region in the face of declining marine resources will ensure that levels of fishing effort remain high unless alternative livelihoods are available. Marine ornamental fish aquaculture will provide another much-needed livelihood option for fishers in the region. Its development, however, needs to be guided carefully in order to ensure that fishers indeed benefit from shifting to aquaculture. This requires a multifaceted approach that combines the development of suitable techniques with socioeconomic initiatives such as the development of community-based cooperatives, and sound business strategies such as the "eco-labelling" of cultured fish.

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The management challenges of Vanuatu's developing marine aquarium fish trade

Being Yeeting[1] and Kalo Pakoa[2]

The marine aquarium trade is a fairly new fishery in the Pacific, first appearing in the late 1970s, with full commercial operations appearing in the early 1980s. This trade involves the small, beautiful reef fish and coral species (live and dead) that traditionally have had little value (as food fish) in Pacific Island coastal communities.

In the last two decades, with the ever-increasing demand for marine aquarium products from hobbyists in the US and Western Europe (the main markets for the trade), the industry has expanded significantly in the insular Pacific, as more and more Pacific Island countries see it as a promising economic opportunity. This is reflected in the dramatic growth in value of marine aquarium exports from Pacific Island countries. The annual value of marine aquarium finfish exports from the Pacific Islands is presently about 2 million US dollars (USD), or 19% of the value of the global trade, compared to USD 100,000 two decades ago.

In most Pacific Island countries that have participated in the trade, the rapid growth of the industry has exceeded the in-country capacity to manage the trade, and it is proving to be a challenge to most government fisheries departments in the region. Because it is a "non-traditional" fishery in the Pacific region, there is a general lack of experience and understanding of the fishery resources and the dynamics of the trade, which is a further hindrance to management efforts.

Vanuatu's marine aquarium industry provides a good case study. The marine aquarium trade in Vanuatu started 14 years ago as a small industry consisting of three small operators, all based on the southwestern side of the main island of Efate. An average of 20,000 fish were exported each year. In 2002 and 2003, exports had increased to 70,000 fish per year, making marine aquarium fish Vanuatu's most important marine resource export commodity.

Why the sudden increase? Interestingly, the industry now involves only one main company exporting marine aquarium fish. Through the import of highly skilled and experienced staff, the present company has been able to improve the efficiency of its management and operations, including improvements in its handling practices and maintenance of its facilities. This has resulted in very low fish mortality rates of 3–5% and high quality products (a significant improvement from the poor quality products of the past). These improvements in turn have triggered more interest and demand from overseas buyers.

On a regional scale, however, Vanuatu's marine aquarium industry is quite small. Vanuatu contributes 0.5% of all marine aquarium exports from the Pacific, compared with Kiribati at 42% and Solomon Islands at 32%. Although small in the regional context, at the local level Vanuatu's marine aquarium trade has been able to offer some direct economic benefits. Exporters have become a significant client of Air Vanuatu in terms of cargo, and the trade has provided a source of income for local people, both through employment and through the purchase of fishing rights from local resource owners in traditionally owned reef areas.

The recent growth in Vanuatu's marine aquarium trade (in the absence of specific management measures to control the fishery) has triggered concerns. These have been mainly from tour and dive operators, who claim that the aquarium trade is causing considerable damage to the coral reefs and is depleting populations of the small, colourful, coral reef-dwelling fish in some of the popular dive sites. The release of the recent Disney film "Finding Nemo" has sparked additional controversy about the trade. For example, an article in *The Guardian* (21 November 2003, by David Fickling) stated, "A booming trade in aquarium fish, sparked by Finding Nemo, the Disney film featuring clownfish, is endangering the wildlife of the Vanuatu archipelago in the South Pacific." Under pressure from the Vanuatu tour and dive operators' association, in February 2004 the Shefa Provincial Council, which is the local governing body that administers

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Efate, decided to ban the trade in Efate provincial waters. The ban, however, was lifted a few weeks later for legal reasons, and the Vanuatu Fisheries Department has since been given the urgent task of developing a management plan for the trade.

In November 2003, prior to the temporary ban, the Fisheries Department had established a National Aquarium Trade Advisory Committee (NATAC) comprising tour operators, aquarium companies and relevant agencies of the national government. The committee was supposedly an opportunity for different stakeholders to share ideas, concerns and potential solutions that would be acceptable to all. Unfortunately, the differences in interests among the members made it difficult to reach consensus. It became quite evident, however, that a management plan for the trade was necessary.

Given the urgency for this management plan, as well as the lack of resources and in-country capacity in the Vanuatu Fisheries Department (which is typical throughout the Pacific), the Fisheries Department requested assistance from the Secretariat of the Pacific Community (SPC).

The principal author, Being Yeeting, visited Vanuatu in April 2004 to assess the situation and to help the Fisheries Department discuss and develop a practical plan of action. The agreed plan of action recognises the lack of baseline information about aquarium fish resources, as well as the need to collect socioeconomic data on the trade. It also acknowledges the need to involve other resource users in the development of the management plan in order to strike a fair balance between the users and the reef owners. The plan of action also recognizes the need to build the capacity and expertise of local staff in resource survey and monitoring methods.

A second trip to Vanuatu was made in May 2004 to conduct the fieldwork required by the plan of action. This trip involved SPC's Fisheries Management Officer (FMO), Aliti Vunisea, in addition to the principal author, Yeeting. Yeeting trained two divers from the Fisheries Department and two divers from the private sector in the identification of aquarium fish and in using SPC's regionally standardized underwater visual census method. At the same time, SPC's FMO conducted the socioeconomic part of the work, meeting and interviewing people from government departments, the tourism industry, the aquarium trade industry, non-governmental organizations, local communities, and fishers.

Data analysis, and more importantly, the process of interpreting results and incorporating them into management plans, is often a weakness in Pacific Island countries. To ensure that this important work is done properly and the experience gained in doing so is transferred to staff at the Vanuatu Fisheries Department, a three-month attachment at SPC headquarters in Noumea was organized for Vanuatu's Principal Fisheries Officer (and second author of this paper), Kalo Pakoa. Pakoa worked with Yeeting to analyse the data collected from the underwater and socioeconomic surveys and used the results to develop management policies, a monitoring program, and a proposed management plan for Vanuatu's marine aquarium trade. He will present these to stakeholders for their comments and inputs. The next step will be to submit these products to the Vanuatu government for approval and implementation. SPC will continue to provide technical assistance well into the implementation stage.

Some of the strategies that are being considered for the new management plan include:

- Development and enforcement of conditions and requirements for operators.
- Revision of the legal framework to improve licensing requirements and to accommodate the new proposed management plan.
- Regulation of areas (zoning, no-take areas).
- Regulation of resources (quotas, size limits).
- Regulation of fishing effort (diffusion to outer islands, restricting number of operators, revision of licensing systems).
- Improved monitoring (of the resource, of operations, of exports).
- Increase benefits to, and participation of, communities through greater involvement in management and in low technology based operations.

The authors' view, and indeed the recent experience in several countries, is that the marine aquarium industry could be a major export industry for Pacific Island countries. But it will be a sustainable trade only if it is managed and monitored effectively.

The Vanuatu marine aquarium trade is an excellent case study of interest to all Pacific Island countries. The Secretariat of the Pacific Community held a discussion session on the aquarium trade at its 4th Heads of Fisheries Meeting in Noumea, New Caledonia, in August 2004. At the meeting, Vanuatu shared its experiences with other countries.

Pre-settlement fish capture and culture workshop, Solomon Islands

Cathy Hair[1]

As part of an ongoing program to develop sustainable artisanal fisheries in Pacific Island countries, the WorldFish Center (formerly ICLARM) regional office in Gizo, Solomon Islands, hosted a workshop from 14–18 June 2004. The training was aimed at rural coastal community members and focussed on operating a fishery based on the collection and grow-out of pre-settlement (or post-larval) reef fish and crustaceans.

The workshop disseminated the practical results of recent WorldFish Center research on "Development of new artisanal fisheries based on the capture and culture of postlarval coral reef fish", a five-year study funded by the Australian Centre for International Agricultural Research (ACIAR) (see article by Hair and Doherty in issue 11 of this bulletin). It was carried out in collaboration with the Australian Institute of Marine Science and the Solomon Islands Department of Fisheries and Marine Resources. The project comprised four years of research and monitoring of pre-settler supply from 1999 to 2002 and a follow-up year (2003) of fine-tuning the methodology. The research showed that the harvest of pre-settlement coral reef species from shallow reef crests could sustain a profitable fishery. In particular, cleaner shrimp, lobster and a range of sought-after aquarium species received good farm-gate prices from the local exporter. Monthly sampling over a two-year period showed that there were sufficient catches of high-value species year-round to support an artisanal fishery. The fishery could provide an alternative livelihood for coastal communities and has potential to reduce the extent of destructive fishing.

ACIAR funded the workshop under a new project that commenced in early 2004. *Sustainable aquaculture development in Pacific Islands region and northern Australia* is administered by the Queensland Department of Primary Industries and Fisheries in partnership with WorldFish and the Secretariat of the Pacific Community.

Harvesting pre-settlement fish is a new activity for Solomon Islanders, although this resource has been exploited in other Pacific Island countries in recent years (e.g. New Caledonia and French Polynesia). The fishery is based on collection and grow-out of pre-settlers, captured at the end of their oceanic dispersal phase when they return to settle on coral reefs. The high mortality associated with this phase of their life cycle provides an ideal opportunity to collect a portion of the returnees for culture and subsequent sale. Furthermore, the gear does not damage reefs and mortality of bycatch is low. Live pre-settlers are harvested using modified crest nets and lobster pueruli collectors developed by WorldFish. Most species are reared for one to three months before being sold to an aquarium fish exporter in the capital, Honiara. The techniques involve simple and low cost technology appropriate for village use, unlike similar fisheries elsewhere that are more capital intensive.

Regon Warren, Ambo Tewaki (WorldFish Center) and Wali Phillips (Gizo Provincial Fisheries) provided the technical expertise for the workshop. Four participants came from the communities of Rarumana and Mbabanga Island in Western Province. These villages are adjacent to suitable collecting areas and in close proximity to Gizo, which is important for follow-up extension activities. National and Provincial Fisheries Officers also took part in the training in order to assist communities in their home provinces should they wish to take up the technology.

Participants were trained in all aspects of the fishery, including how to catch pre-settlers on shallow reefs, grow them to a marketable size and then freight them to the exporter. Construction of collectors, holding nets and other equipment was demonstrated and practised. Attendees also learned how to recognize and handle valuable species, with emphasis on shrimp, lobster and attractive aquarium fish, such as angelfish and butterflyfish. Participants agreed that the training was very useful and were enthusiastic about the hands-on approach encouraged by the trainers. It provided an educational opportunity as well, with great interest shown in pre-settlement fish and how they changed in appearance following capture. A draft manual was used for training. Comments on the strengths and weaknesses of the manual were compiled during the workshop and

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these comments will be used to revise the text before a final version is produced.

With basic training completed, the next step is to establish demonstration village "farms" to test the methods in a rural situation. WorldFish will continue to support the two Western Province communities with the fledgling fishery. The final manual will be produced in an easy-to-follow pictorial style sometime in early 2005. One of the aims of the current ACIAR project is to transfer the technology elsewhere in Solomon Islands and to other Pacific Island countries. Updates on the results of extension efforts will be reported in future issues of this bulletin.

Figure 1. **Catch being retrieved from a crest net.**

Figure 2. **Workshop participants practice rearing shrimp in jars in a raceway.**

Seahorses take to the world stage

Heather Koldewey[1]

The most charismatic of fish, seahorses, are now subject to regulations that affect their movement across national borders. The new rules have generated debate as aquarists ponder the implications of the listing of all 34 known species of the genus *Hippocampus* by the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). Though they present some challenges to the aquarist community, the mechanics of the treaty are relatively straightforward, and anyone interested in keeping and trading seahorses should become familiar with them. Aquarists are significant buyers of seahorses, and have a role to play in the global effort to ensure the survival of seahorses and their habitats.

CITES is an international agreement between more than 160 nations that aims to ensure the international trade in plants and animals does not threaten their survival in the wild. Some 30,000 species are covered by CITES, which lists them in three Appendices. The first covers species threatened with extinction. Trade in these species is banned except under exceptional circumstances. Appendix II species may become threatened if trade is not regulated, and Appendix III lists species at the request of countries needing help protecting local populations.

CITES agreed in 2002 to place all seahorses in Appendix II. The decision was built on careful analyses of the trade and the conservation status of wild populations, along with growing support among fishers and dealers. More than 24 million seahorses are traded annually among almost 80 nations, making them one of the world's largest wildlife management issues. The listing also opens the door to what many hope will be a new era for CITES, as commercially important fully marine fish had never before been placed under binding international regulation. (See article by Sadovy in issue number 11 of this bulletin for more detail on

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the history of CITES with respect to marine fish and species popular in the live fish trade.[2])

The seahorse listing took effect on 15 May 2004. Countries wishing to export seahorses now have to prove the exports do not threaten existing wild populations (known as "non-detriment findings"). But many countries are presently unable to adequately assess the sustainability of seahorse exports, as data on populations, fisheries and trade are sparse or nonexistent. As a result, and following a proposal by Project Seahorse, a CITES technical advisory panel known as the Animals Committee formally approved a 10 cm minimum size limit as an interim management tool to support "non-detriment findings" (with a few limited potential exceptions relating to smaller species). In April 2004, the CITES Secretariat recommended that member countries implement the minimum size limit, at least until they assess international trade levels, impacts on domestic populations, and other long-term management tools for making non-detriment findings.

A minimum size is a simple but powerful tool. The recommended limit of 10 cm (as measured from the top of the coronet to the tip of the straightened tail — see Fig. 1) is not just a round, convenient number. It is slightly greater than the maximum recorded height at first maturity for most species, and most seahorses of that size have had a chance to reproduce. A minimum size is also believed to be the favoured management option among many of those whose livelihoods depend on the trade.[3] Minimum size limits are easily understood and enforceable. Fishers can determine whether they are complying with their obligations simply by measuring their catch, as can fisheries enforcement officers and customs officials. Countries are free to consider other options, such as no-take zones, closed seasons and gear restrictions, but in the near future the minimum size will likely be the tool of choice of most CITES signatories. Trade in the smaller seahorses often favoured by hobbyists and aquariums is affected by the limit, but only in the case of imports of wild-caught species. Aquarists still have access to captive-bred species and seahorses caught and sold within national borders.

Figure 1.
Height measurement to be made for specimens of seahorses of wild origin in trade, as recommended by the CITES Animals Committee.

Photo illustration by James Hrynyshyn/Project Seahorse.

There are currently many challenges facing those involved in the live trade, transportation and care of seahorses. The latest data show that the volume, scope and interconnectedness of the trade have grown since the first trade survey was published in 1996. All sectors of the seahorse fishery have a role to play as we develop robust and flexible conservation plans. Improved husbandry, handling and transport practices are needed to better acclimatize wild-caught seahorses to captive conditions. The Marine Aquarium Council (http://www.aquariumcouncil.org) and similar organizations may be useful in encouraging better management through certification. All aquarists should consider the conservation status of seahorses when making their consumer choices. With a concerted effort on all our parts, seahorses will continue to amaze and fascinate for the foreseeable future.

What you can do:

- Familiarize yourself with CITES and your national and regional wildlife regulations; national regulations may be stricter (as in the European Union) than CITES.
- Ask questions about the source of any specimens.
- Use informed and reliable retailers and suppliers.
- Support marine conservation organizations that use best-available science and respect the communities and groups that rely on those resources.

Project Seahorse is an international and interdisciplinary marine conservation organization with offices in Australia, Canada, Hong Kong, the Philippines, the UK and USA. Its website is http://www.projectseahorse.org. For more information on CITES, visit www.cites.org. For information regarding wildlife trade regulations of the European Union, go to http://www.eu-wildlifetrade.org.

2. http://www.spc.int/coastfish/News/lrf/11/LRF11-Sadovy.pdf
3. See: Martin-Smith, K.M., Samoilys M.A., Meeuwig J.J. and Vincent A.C.J. 2004. Collaborative development of management options for an artisanal fishery for seahorses in the central Philippines. Ocean & Coastal Management 47(3–4):165–193.

Economic and market analysis of the live reef food fish trade in the Asia-Pacific region

Geoffrey Muldoon[1], Liz Peterson[2], Brian Johnston[3]

Introduction

In 1998 the Australian Centre for International Agricultural Research (ACIAR) funded a project to look at the "Sustainable Management of the Live Reef Fish Trade-Based Fishery in Solomon Islands". A review of this project, which concluded in 2001, indicated that detailed economic analysis of marketing of the live reef fish trade would provide significant benefits to a range of stakeholders (Fegan 2002). Subsequently, it was acknowledged that any economic analysis should be extended to incorporate the whole Asia-Pacific region and include key Asian producers of live reef food fish (LRFF), which have a longer and more active history in the LRFF trade than Pacific Island producers. As such, the study will focus on the following supply countries: Indonesia, Australia, Papua New Guinea, Vietnam, Fiji and Solomon Islands.[4] Other key suppliers such as Thailand and the Philippines will be incorporated through the involvement of multilateral agencies such as the WorldFish Center in Malaysia and the Network of Aquaculture Centres in Asia-Pacific (NACA).

In July 2003, a nine-month feasibility study was commissioned by ACIAR, with a view to developing a more comprehensive proposal. The feasibility study undertook a review of a number of aspects relating to the trade, including: availability of price, quantity and trade data; suitable methods for quantifying short- and long-term demand and supply of live reef fish; suitable economic frameworks for measuring the beneficiaries of improvements in demand or supply; and key cost and risk components of the marketing chain. In addition, a network of potential collaborating organizations and universities were identified, such as the Secretariat of the Pacific Community (SPC), the WorldFish Center and Bogor University (Indonesia). Linkages with other ACIAR projects relating to improved technology for hatchery and grow-out of marine finfish in the Asia-Pacific (FIS/2002/077) were also established.

In concluding the feasibility study, a proposal for a larger two-year project was submitted to ACIAR, "Economic and Market Analysis of the Live Reef Fish Food Trade in Asia-Pacific". The project is expected to commence in July 2004 with a research team comprising Dr Brian Johnston as project leader, Dr Elizabeth Petersen and Mr Geoffrey Muldoon. It will also include research collaborators Dr Mahfuzuddin Ahmed, Dr Madan Dey and Dr Reohlano Briones from the WorldFish Center, Mr Being Yeeting from SPC, Dr Akhmad Fauzi from Bogor University and Dr Sonny Koeshendrajana from the Research Institute for Fisheries Product Processing and Social Economics, Jakarta. The remainder of this article provides some information on the trade and an overview of the proposed project.

Background

Live reef food fish are currently sourced from more than 20 countries in the Asia-Pacific region, some located close to Hong Kong having been in the trade for some time while other more distant countries are only recent, and infrequent, participants (Petersen et al. 2004). Total recorded imports of LRFF into Hong Kong, while declining from the peaks of the late 1990s, have remained stable since then (Fig. 1).

Recent estimates, based on declared imports of LRFF into Hong Kong, place the annual volume of trade into Hong Kong at 13–14,000 tonnes (t), with a retail value of approximately 350 million US dollars (USD). As there is no requirement for the approximately 100 Hong Kong licensed live-fish transport vessels to declare imports entering Hong Kong by sea, these estimates are almost certainly lower than actual imports, which are more likely to be 15–20,000 t annually. The total regional trade has been estimated to be as high as 30,000 t per year (Sadovy et al. 2004).

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3. Asia-Pacific School of Economics and Government, Australian National University. Email: njvj@austarmetro.com.au
4. Although not presently a supplying country, Solomon Islands has in the past supported a LRFF fishery and there is potential for a LRFF fishery to reopen in the future.

As noted, a range of undesirable economic, environmental and social outcomes have been identified as being associated with the trade, with the focus mainly on environmental issues. These include overexploitation of coral reefs and coral reef fish and the environmentally damaging aspects of some harvesting techniques, including cyanide fishing, targeting of spawning aggregations and the capture of immature fingerlings and juveniles for grow-out (Cesar et al. 2000; Sadovy and Vincent 2002). Other aspects of the trade are not well understood and would benefit from further research, including detailed empirical analysis of demand and supply issues.

Supply analysis can enable investigation of supply responses of fishers and traders in various countries to changes in prices, based on historical data. On the demand side, the future market potential for wild-caught and cultured live reef product is largely unknown. Demand analysis can enable investigation of how consumer preferences for certain LRFF species change in response to changing prices and incomes and the effects of these changes on quantities of LRFF imported. Substitution among the various wild-caught species and between wild-caught and aquaculture species is of particular interest, as this will enable predictions of short- and long-term consumer demand.

As incomes in Asia rise over the next decade and aquaculture products become more readily available, there is an expectation that consumer demand for LRFF will likewise increase. The trade, however, is susceptible to the economic environment, as evidenced in a downturn during the Asian economic crisis. The region has not yet fully recovered from the crisis or from the Severe Acute Respiratory Syndrome (SARS) outbreak.

For the purposes of this article, common names used by the Agriculture, Fisheries and Conservation Department (AFCD) in Hong Kong, China are preferred (Table 1).

Trade data and recent economic events

Total recorded imports into Hong Kong have remained fairly stable since 1999, when import volumes declined considerably relative to previous years (Fig. 1). Hong Kong's economy remained fairly robust for the duration of the Asian economic crisis that began in 1997, and only began to show signs of a downturn from the end of 1998. This downturn coincided with a fall in declared imports of approximately 30% in 1999, mainly in the categories of the lower-value "other marine fish" and "other groupers". In 2003, while total imports into Hong Kong rose slightly (by less than 0.5%), the

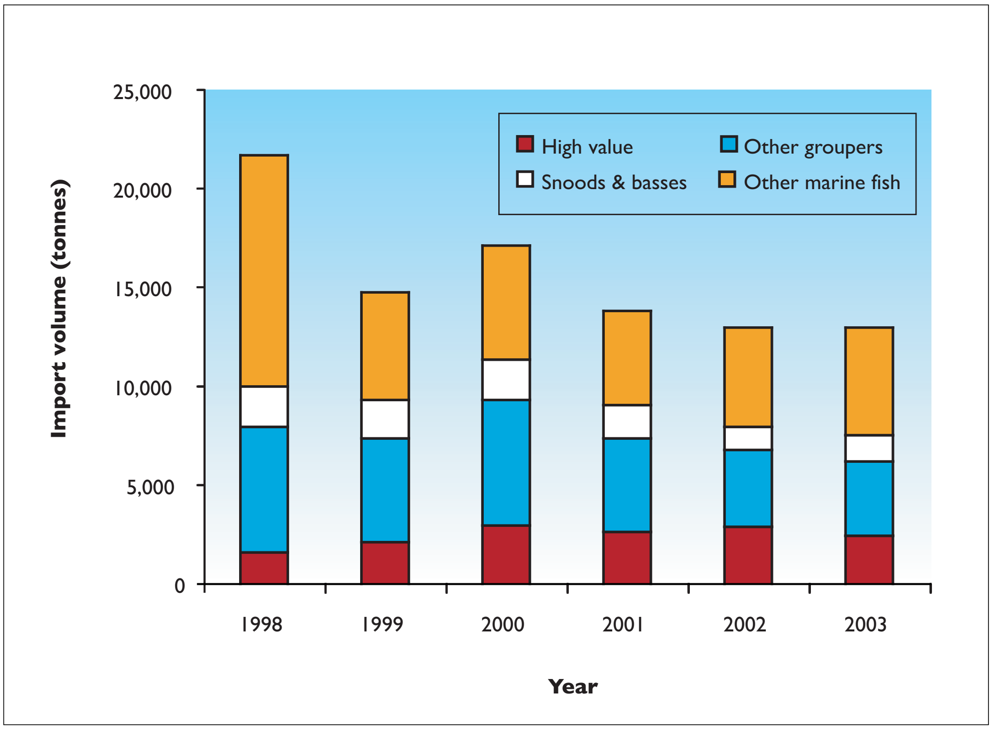

Figure 1. Annual volumes of reported imports of all live reef food fish into Hong Kong from 1998 through 2003. High value species include highfin grouper, humphead wrasse, giant grouper, leopard coralgrouper, and spotted coralgrouper. Other groupers include the green grouper, tiger grouper, flowery grouper and other groupers. Other marine fish include wrasses and parrotfish, mangrove snapper and other fish (Source: unpublished data from Hong Kong, China Census and Statistics Department and the Agriculture, Fisheries and Conservation Department).

SARS epidemic during that year may have influenced consumer demand for particular species. In 2003, the volume of high-value imports fell by 15%. In contrast imports of the lower-value "other marine fish" category, which had declined in three of four previous years, rose 10%.

Anecdotal evidence suggests a number of market responses to SARS influenced these changing consumption patterns. Following the first SARS reports in Hong Kong, restaurants began reporting cancellations of banquet bookings. Restaurants are traditionally the place where the higher-value and medium-value species are purchased and consumed, and so consequently much of their product is imported from overseas sources. With the number of patrons dining out at these restaurants falling markedly, many restaurants closed down for the duration of the SARS scare and, with the lower demand for high- and medium-value fish, many traders stopped buying fish from overseas suppliers. Conversely, with consumers preferring to eat fish at home as opposed to dining out, the demand for the lower-value and domestically caught fish is thought to have increased.[5]

The impact of the SARS epidemic, during April and May of 2003, on individual species can be examined by looking at trends in both prices and import volumes across recent years. There were no real discernable impacts of SARS on the import prices of most high-value and mid-value species (see Fig. 1 caption), including leopard and spotted coralgrouper, highfin grouper, green grouper and tiger and flowery grouper (Pet-Soede et al. 2004). The SARS epidemic however, does appear to have had an impact on the demand for a subset of high-value species and other grouper species. Figure 2, which compares monthly imports in 2003 and monthly imports averaged across the years 2000–2002, illustrates declines in imports of four key species or species groups in the months affected by the SARS epidemic. In April and May of 2003 imports of leopard coralgrouper were 34% and 48% lower, respectively, than the average annual imports over the years 2000–2002. Imports were also lower for green grouper and tiger grouper in April (39% and 11% lower, respectively) and May (16% and 1% lower, respectively). While imports of flowery grouper were 48% lower in April than the 2000–2002 average, imports in May were 31% higher than the 2000–2002 average. While recognising that the SARS event was likely a market demand phenomenon, it is possible that supply constraints influenced these observed declines in import volumes.[6]

During the SARS outbreak, imports from countries in closer proximity to the Hong Kong market did not decline by as much as those from countries farther away, compared with previous years. For example, imports of leopard coralgrouper from the Philippines were not significantly lower than the 2000–2002 average, while imports of this species from Australia dropped by roughly 50% in both April and May 2003. One reason might be that proximity implies lower transport costs, and hence lower total import costs, while another would be the availability of substitute markets. In Australia, local wholesalers reported beach prices being offered to fishers for live fish as low as 15 Australian dollars (AUD) per kilogram during the peak of the SARS outbreak, compared with an average price in April and May across all years from 1997 to 2002 of AUD 25.1 and AUD 25.9, respectively. Moreover, beach prices for frozen and whole fresh fish during April and May of 2003 remained steady at between AUD 16.00 and 19.00 per kilogram, depending on the weight of the fish (G. Muldoon, unpublished data; T. Must, Fish Wholesaler, pers. comm.). According to several wholesale buyers spoken to during and after the SARS outbreak, many fishermen in Australia either sold their fish fresh or frozen to domestic and overseas markets rather than live, or did not fish at all during this period.

Table 1. **Common fish species names used in this article.**

Common name	Scientific name	Common name	Scientific name
Highfin grouper	*Cromileptes altivelis*	Tiger grouper	*Epinephelus fuscoguttatus*
Humphead wrasse	*Cheilinus undulatus*	Flowery grouper	*Epinephelus polyphekadion*
Leopard coralgrouper	*Plectropomus leopardus*	Green grouper	*Epinephelus coioides*
Spotted coralgrouper	*Plectropomus maculatus*	Giant grouper	*Epinephelus lanceolatus*
Mangrove snapper	*Lutjanus argentimaculatus*		

5. Patrick Chan (Chairman, Hong Kong Chamber of Seafood Merchants), personal communication.
6. Supply constraints in source countries may be related to weather (monsoon, high winds) or seasonal variations in catch rates.

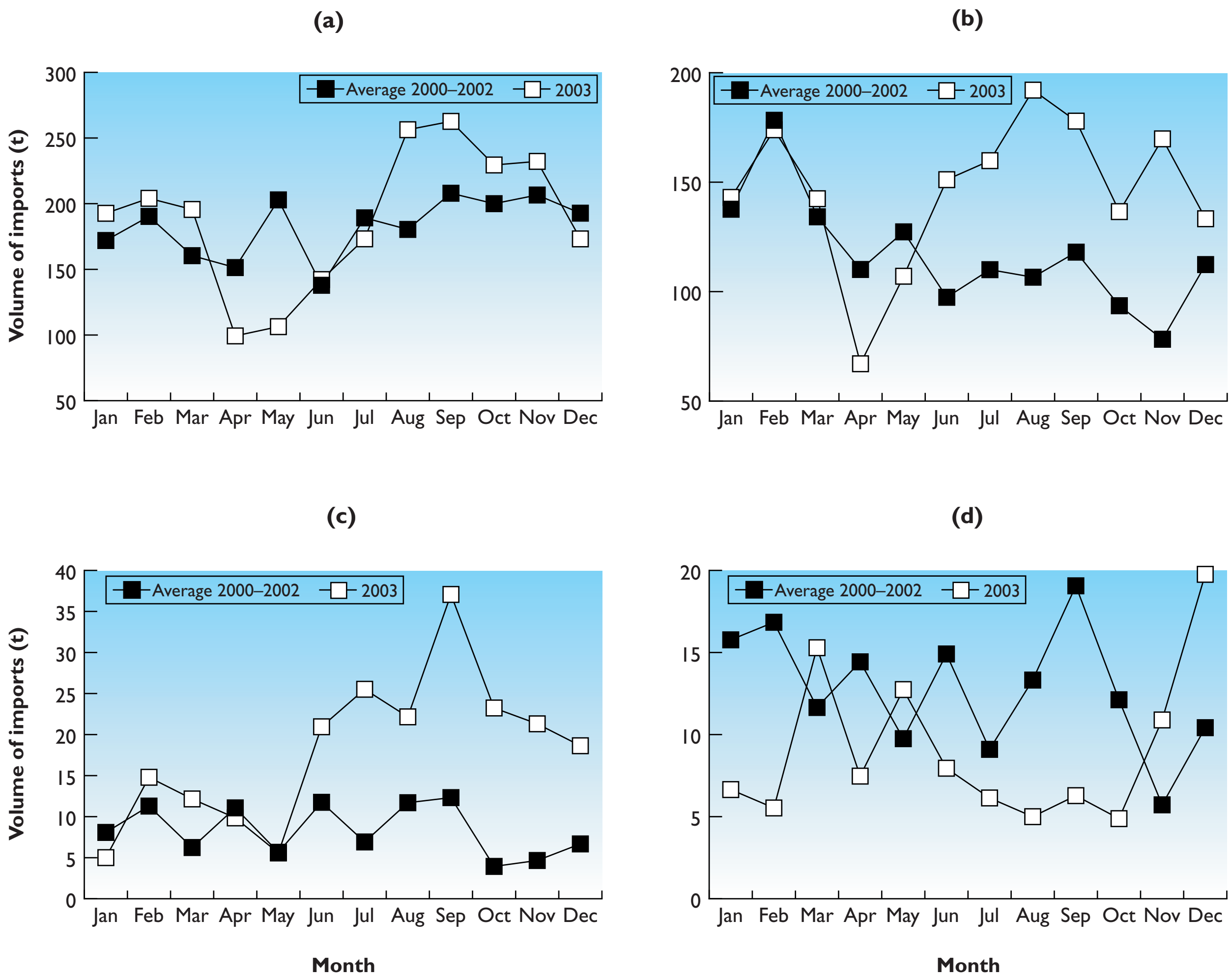

Figure 2. Total monthly volume of imports of four major species or species groups: a) leopard coralgrouper, b) green grouper, c) tiger grouper, and d) flowery grouper, imported into Hong Kong from 2000 through 2003. Monthly import volumes have been averaged across the years 2000–2002 (Source: unpublished data from Hong Kong, China Census and Statistics Department and the Agriculture, Fisheries and Conservation Department).

Pet-Soede et al. (2004) noted in a previous issue of this bulletin that prices of two high-value species, leopard coralgrouper and highfin grouper, showed little, if any, change in price in response to SARS. They did, however, note substantial price reductions in beach prices received by fishers in Indonesia for live grouper. Similarly discounted prices were "offered" to fishers in Australia, with beach prices during the SARS outbreak 40% lower than average prices for those months over the previous five years (G. Muldoon unpublished data). Although only anecdotal accounts are available for the Philippines, live fish exporters noted that beach prices paid to fishers fell by 20% during the SARS outbreak (B. Cheng pers. comm.). These discrepancies in price variations (in response to SARS) that were experienced by participants in supply and demand countries may be cause to point to market distortions and profit-taking by retailers in Hong Kong, at the expense of fishers and middlemen in supplying countries. Such inferences, however, based on these observations and with limited knowledge of the dynamics of supply and demand, would be difficult to substantiate.

A similar picture emerges for a broader range of species, including mid-value species, such that available data do not provide strong evidence of a SARS impact on price (Fig. 3). Figure 3 compares monthly retail prices in 2003 with monthly retail prices averaged across the years 2000–2002 for four species of grouper. Ignoring SARS impacts, what is of interest is that for all species, with the exception of April for the leopard coralgrouper, monthly retail prices in 2003 were lower than the corresponding monthly retail prices averaged across 2000–2002. This reinforces the anecdotal evidence provided by traders of a downward trend in prices for the whole trade. Again, discerning whether these price variations may be demand or supply

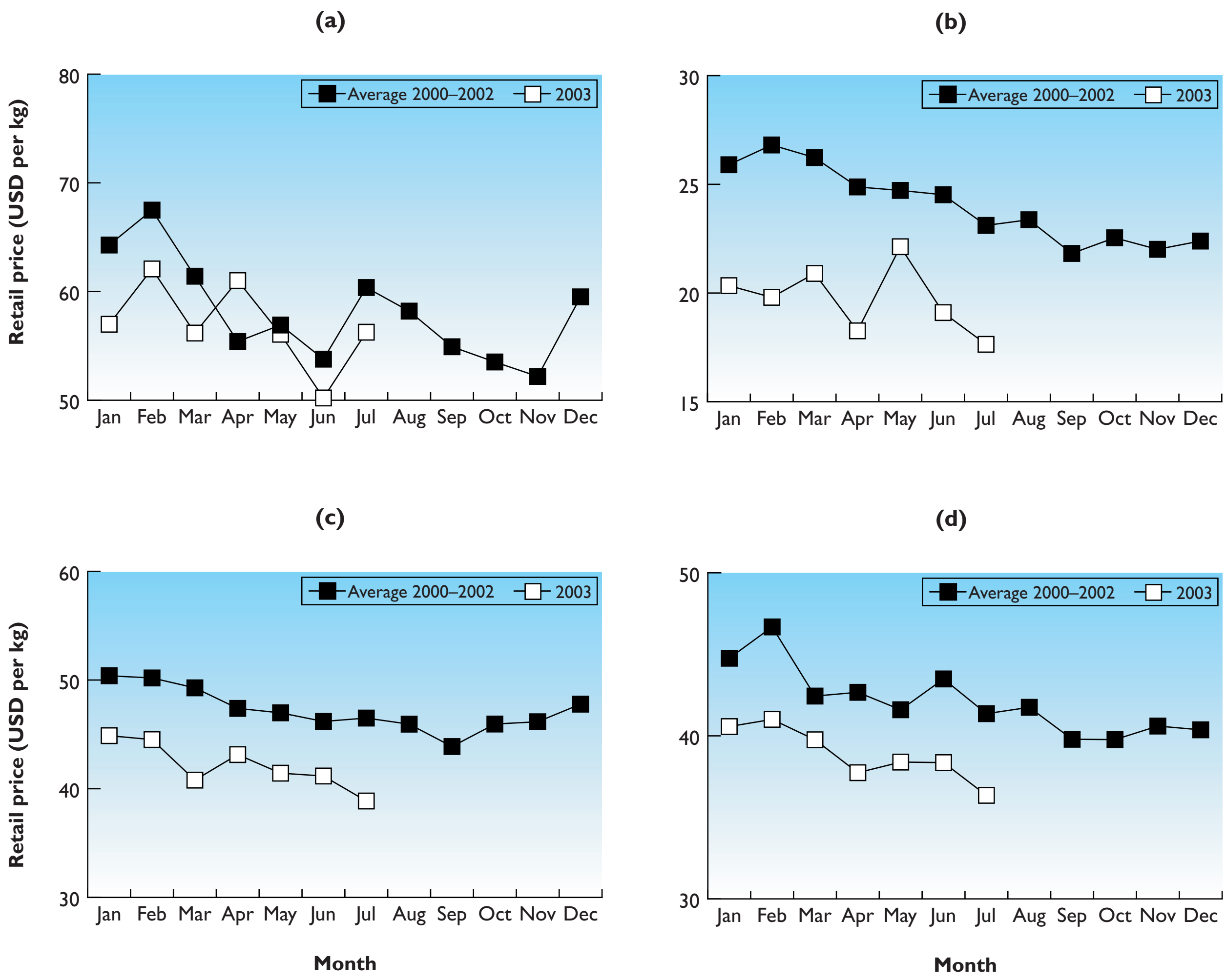

Figure 3. Monthly retail prices in Hong Kong of four major species or species categories: a) leopard coralgrouper, b) green grouper, c) tiger grouper, and d) flowery grouper, imported into Hong Kong from 2000 through 2003. Monthly retail prices have been averaged across the years 2000–2002, while monthly retail prices for 2003 are only available until July of that year (Source: unpublished data from International Marinelife Alliance, Hong Kong).

responses is difficult based on available data. While prices in 2003 were lower for all species illustrated, patterns of import volumes were not consistent. For example, leopard coralgrouper imports increased relative to the previous year in 2000 (44%) and 2002 (11%) but were stable in 2001, while tiger grouper imports increased in 2000 (36%), 2001 (16%) and 2002 (21%). In contrast, green grouper imports decreased in 2000 (13%), 2001 (5%) and 2002 (20%), as did flowery grouper imports in 2000 (45%), 2001 (7%) and 2002 (12%). A hypothesis that suggests declines in import volumes should lead to price increases is not borne out here. A more likely premise is that the market overall is depressed, as is the Hong Kong economy generally. Further investigation would be required to establish whether the discrepancies in monthly import volumes between years and corresponding price movements are, in general, supply and/or demand responses.

Aquaculture has been identified as both an alternative livelihood to engaging in often-destructive fishing practices and as a means of meeting future demand for the "higher-value" grouper species when many fish stocks in Southeast Asia are showing signs of severe depletion. It is estimated that approximately 40 per cent of all LRFF in the trade are supplied from aquaculture, although the majority of these fish come from grow-out of wild-caught juveniles to market size.

Any benefits from substituting wild-caught with cultured species depend on how successfully the mariculture industry relieves its dependence on wild stocks for juveniles and trash fish for feed through increased hatchery production and development of new diets (Sadovy et al. 2004). Moreover, the market impacts, and specifically price impacts, of this substitution may have significant effects on fisher income.

ACIAR provides funding assistance to a number of mariculture projects of live reef fish species in Indonesia and Vietnam.[7] Those projects have identified a need for economic analysis to quantify key supply and demand relationships in the market, especially with respect to assessing the potential contribution of mariculture in assisting the long-term sustainability of the trade. This project will be collaborating closely with those projects.

Project overview

The trade in LRFF is largely unregulated, which has led to some undesirable biological, social and economic consequences. The anticipated research outputs from this project will benefit industry participants and management agencies alike, for both existing and potential fisheries. Empirical modelling of supply and demand will enable further analysis of who the major beneficiaries are likely to be from new technologies, economic growth or policy options aimed at improving market performance by, for example, regulation of fishing effort or removing inefficiencies and distortions along the market chain. Another key output will be the inclusion of key cost and revenue components along the market chain, including key risk factors, into a cost-benefit model. A spreadsheet model of the market chain will be constructed that will aid capture fishery managers and the aquaculture sector in assessing the future viability of LRFF capture and aquaculture fisheries in their countries.[8]

The study will focus on the following supplying countries: Indonesia, Philippines, Australia, Papua New Guinea, Thailand, Vietnam, Fiji and the Solomon Islands (although the Solomon Islands is currently not a LRFF supply country it has been in the past and has some potential in the future). During the feasibility study phase of this project, collaborative partnerships were established with the WorldFish Center, SPC and Bogor University. The first is hosting a regional collaborative project involving mainland China, Indonesia, Malaysia, Philippines, Thailand and Vietnam, looking at "Fish Supply and Demand in Asia", while the latter two will assist with information on developments in LRFF fisheries in Southeast Asia and the Pacific.

The overall aim of the project is to enhance the sustainable economic development of the live reef food fish trade, through economic analysis of policy options for improving market performance. The main beneficiaries of this research are likely to be small-scale and subsistence fishers in supplying countries and government agencies charged with the sustainable management of their wild-caught fisheries and investigating the potential for mariculture.

The specific research objectives of the project are to:

1) quantify short- and long-term demand of LRFF in Hong Kong and southern mainland China sourced from the Asia-Pacific region, including developing countries;
2) quantify short- and long-term supply of LRFF from wild-caught and aquaculture production sourced from the Asia-Pacific region, including developing countries;
3) measure the key cost and risk components of the marketing chain;
4) quantify likely future changes in supply and demand for LRFF arising from new technology, management practices and economic growth, and to identify the beneficiaries of these developments;
5) identify the highly-valued product attributes (e.g. colour, taste, texture) of wild-caught and aquacultured LRFF product and to examine these preferences through panel taste evaluation tests;
6) identify possible policy options to improve market performance such as catch and effort controls and adoption of improved technologies in production, storage and transportation; and
7) build capacity in economic assessment throughout the Asia-Pacific region in order to provide and coordinate economic research and disseminate information on the trade utilising the existing LRFF research and development networks (NACA, SPC, WorldFish Center).

Key research outputs of the project are:

- empirical modelling of supply and demand, taking account where possible of new technologies, changing consumption patterns and income growth;
- policy analysis for improving market outcomes for the industry in various stages of the marketing chain (including options for fishery regulation) and identification of the beneficiaries of market improvements;

7. Projects include FIS/1997/073 "Improved hatchery and grow-out technology for grouper aquaculture in the Asia-Pacific region", FIS/2002/077 "Improved hatchery and grow-out technology for marine finfish aquaculture in Asia-Pacific region" and FIS/2003/027 "Environmental impacts of marine cage aquaculture in Australia and Indonesia".
8. In A Collaborative Strategy to Address the Live Reef Food Fish Trade (Graham 2001), developing a cost-effective method for assessing the viability of export-based LRFF fisheries was identified as a key objective.

- a spreadsheet model of all costs and revenues along the market chain, including risk factors, for Australia and two Southeast Asian and two Pacific supply countries to aid fishery managers and the aquaculture sector to assess the future viability of LRFF capture and aquaculture fisheries in their countries; and
- dissemination of the results of consumer preference surveys comparing attributes of wild-caught and aquacultured LRFF products to other ACIAR and NACA mariculture research projects in order to improve hatchery production technologies and the development of new diets.

The information from these outputs will feed into a number of forums over the two-year course of the project. These include research workshops to be held in conjunction with key research collaborators in the region, workshops held by the ACIAR Mariculture Grouper project, the Asia-Pacific Economic Cooperation (APEC) Fisheries Working Group project to develop Industry Standards,[9] the annual conferences of the Australian Agricultural and Resource Economics Society (AARES) and the biennial international conference of the International Institute of Fisheries Economics and Trade (IIFET). There are also good extension opportunities for the outputs of the project through the SPC Live Reef Fish extension network.

Anyone interested in finding out more about the project or discussing it with project participants is encouraged to contact the authors.

Acknowledgements

The authors would like to thank T. Must (Arabon Seafoods) Patrick Chan (Hong Kong Chamber of Seafood Merchants) and Benzon Cheng (Sea Dragon) for their personal comments and observations. Thanks also are extended to Thomas Graham for his valuable comments and suggestions.

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9. For an overview of the Industry Standards project see the article by Kusumaatmadja et al. in the previous issue of this Bulletin (Number 12, February 2004, pages 30–33, http://www.spc.int/coastfish/News/LRF/12/index.htm).

Humphead wrasse listed on CITES

Yvonne Sadovy[1]

The humphead wrasse, *Cheilinus undulatus* (Fig. 1), was listed in Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) at the October 2004 Convention of the Parties 13 in Bangkok. The listing is to be implemented within 90 days of the CITES meeting (i.e. by mid-January, 2005) and, while still allowing local capture and international trade, is intended to ensure that the species is fished sustainably. Because CITES is a powerful and binding international convention for signatory "Parties", source countries for the humphead wrasse must introduce or enforce existing management measures for the species, or otherwise ensure its sustainable use. In the long term, the CITES listing should not only benefit this species, but will hopefully also focus much-needed attention on the difficulties of achieving sustainable use of biologically vulnerable, but commercially valuable, reef fish, particularly those under pressure from growing export markets.

Appendix II is relevant to species that are "not necessarily now threatened with extinction but that may become so unless trade is closely controlled". The biology of the humphead wrasse (also known in English as the Napoleon wrasse or Maori wrasse) and the manner in which it is often fished make it particularly susceptible to uncontrolled exploitation. The species is large and lives a long time, characteristics in marine fishes that typically mean that they are not particularly productive. Adults (i.e. typically those larger than about 40–50 cm in length) are nowhere common, and tend to occur mainly in limited outer reef habitats where they spawn (reproduce) in small aggregations. Smaller humphead wrasses (i.e. juveniles), on the other hand, are heavily targeted for the international live reef food fish trade. These "plate-sized" fish are exported directly after capture or put in floating cages in the sea for several months to "grow-out" to preferred market sizes.

The humphead wrasse is a highly favoured fish, both for traditional use in the western Pacific and, increasingly within the last decade, as part of the live reef food fish trade in which it gains high retail prices in restaurants and yields a good profit margin. Because it is readily taken by cyanide, or at night in its resting places, it is easy to catch. Imports are centred in Hong Kong, although much of the volume now passes into mainland China. Demand for live fish in this luxury international trade is predicted to grow due to increasing wealth within the region.

Although well suited for an Appendix II CITES listing, there are some substantial challenges ahead in working towards recovery of this species. On the export side, source countries will have to find the means to assess exploited populations and exports of fish. Although, in principle, pressure on wild fish could be reduced by sustainably practiced mariculture, it is likely to be many years before hatchery production of this species can hope to supply a significant proportion of exports; it is even possible that hatchery production may never be viable economically enough to take pres-

Figure 1.
The humphead wrasse, *Cheilinus undulatus*
Image: Les Hata. © SPC

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sure off wild populations. Finally, although Hong Kong is the major importer of this species and has a good CITES record, the very real difficulties of monitoring imports by sea will have to be addressed. All of these challenges will need action from governments, but tertiary institutions and non-governmental organisations could provide substantial support by helping to tackle some of the issues.

For more information on this species see: Sadovy et al. 2003; www.scrfa.org; and www.humphead wrasse. info.

Important details of an Appendix II listing in relation to its international trade have been extracted from the CITES website (www.CITES.org) and include:

- The export of any specimen of a species included in Appendix II shall require the prior grant and presentation of an export permit. An export permit shall only be granted when the following conditions have been met: (a) Scientific Authority of the State of export has advised that such export will not be detrimental to the survival of that species; (b) Management Authority of the State of export is satisfied that the specimen was not obtained in contravention of the laws of that State for the protection of fauna and flora; and (c) Management Authority of the State of export is satisfied that any living specimen will be so prepared and shipped as to minimize the risk of injury, damage to health or cruel treatment.

- International trade in specimens of Appendix-II species may be authorized by the granting of an export permit or re-export certificate; no import permit is necessary (*but imports must be accompanied by export/re-export documentation).* Permits or certificates should only be granted if the relevant authorities are satisfied that certain conditions are met, above all that trade will not be detrimental to the survival of the species in the wild.

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First successful hatchery production of Napoleon wrasse at Gondol Research Institute for Mariculture, Bali

Bejo Slamet[1] and Jhon H. Hutapea[1]

The Napoleon, or humphead, wrasse (*Cheilinus undulatus*) is one of the most expensive live reef food fish in Asian markets, especially Hong Kong, Singapore and China. Because this species is being overfished, many countries in the Asia-Pacific region have regulated its capture and export. Consequently, there is considerable interest in the potential for culturing Napoleon wrasse to supply these high-value markets. The Research Institute for Mariculture (RIM) at Gondol, Bali, Indonesia, initiated research on hatchery production technology for Napoleon wrasse in 1997. Captive broodfish began spawning in 1998, and numerous attempts were made to rear the larvae. After many years of research on gonadal development, spawning and larval rearing, RIM researchers finally produced 120 juvenile Napoleon wrasse in 2003. This is the first reported hatchery production of this species.

Rearing Napoleon larvae is difficult compared to other marine finfish such as snappers and groupers. The difficulty is related to the small size of the newly hatched larvae and their small mouth gape. Egg diameter is only 620–670 micrometers (µm), the total length of newly hatched larvae is 1.5–1.7 millimeters (mm), and mouth gape at initial feeding is only 133 µm.

RIM researchers attribute the successful larval rearing to the provision of high quality feed to broodstock, resulting in good quality eggs. In addition, researchers were able to provide good quality and appropriately sized live food (40–80 µm) to the larvae during the initial feeding period before the yolk and oil globule were exhausted.

RIM researchers note that the growth of Napoleon wrasse is extremely slow; at around six months of

1. Research Institute for Mariculture at Gondol, Bali, Indonesia. Email: gondol_dkp@singaraja.wasantara.net.id

age the juveniles were only 5–6 cm in total length. This feature may limit their attractiveness for aquaculture, despite the high price of this species in the live reef food fish trade.

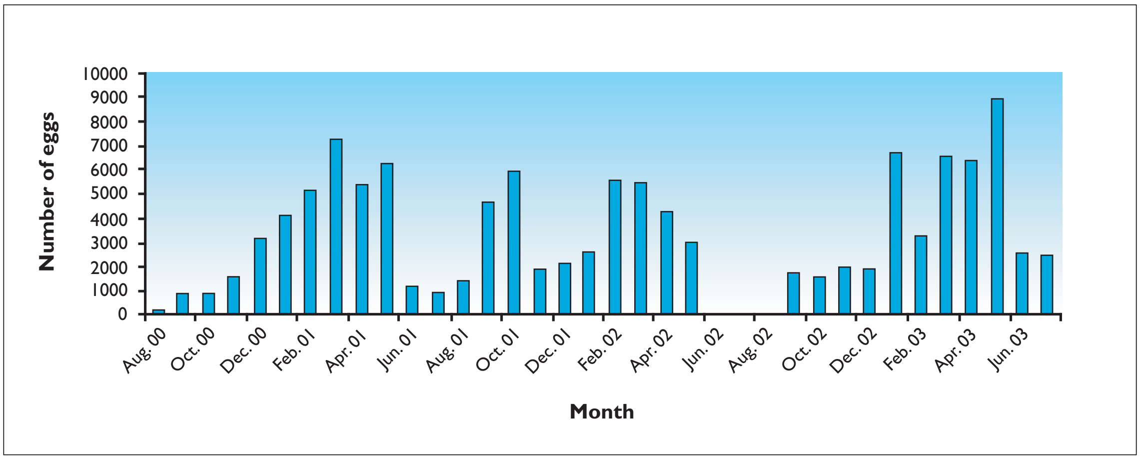

Figure 1. Egg production by Napoleon wrasse broodfish at Research Institute for Mariculture, Gondol, Bali, from 2000 to 2003.

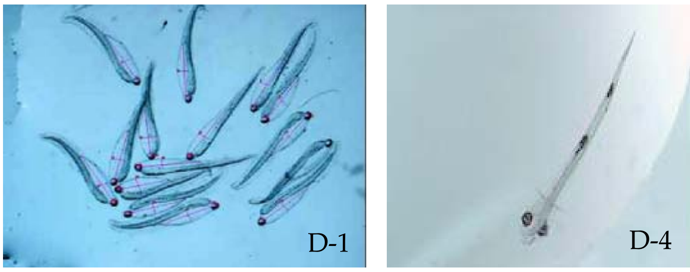

Figure 2. Napoleon wrasse larvae one day (D-1) and four days (D-4) after hatching.

Figure 3. Napoleon wrasse hatchery-raised juvenile.

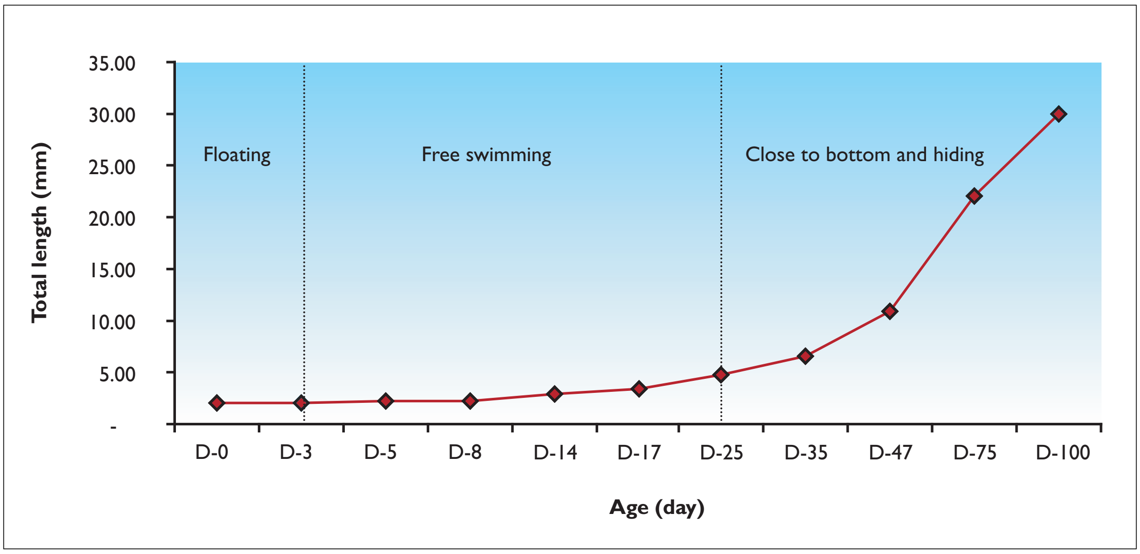

Figure 4. Growth pattern and behaviour of Napoleon wrasse larvae.

Spawning and larval rearing of coral trout at Gondol

Ketut Suwirya[1]

Coral trout, *Plectropomus leopardus*, is a popular candidate for mariculture in the Asia-Pacific region. The Research Institute for Mariculture (RIM) at Gondol, Bali, Indonesia, is currently researching the development of hatchery technology for this species, known locally as *sunu*. Ninety wild broodfish, ranging from 1.3 to 3.5 kg, were collected in 2003 and 2004. Sixty broodfish were maintained in a 150 m^3 concrete tank, and the remainder in a 100 m^3 concrete tank — both tanks were supplied with flow-through seawater at ambient temperature. Coral trout broodfish were fed trash fish and squid (2:1 ratio). The fish commenced spawning after seven months in the broodstock tanks and produced between 500,000 and 2,500,000 eggs per day (both tanks combined) for three to seven days each month.

Fertilized eggs were stocked in a 5 m^3 concrete larval rearing tank. Starting on the second day after hatching (D2), larvae were fed with rotifer at a density of 5 per milliliter (ml). Rotifer density in the larval rearing tank was maintained at 10 to 30 per ml until D27. From D19, larvae were fed *Artemia nauplii*, and *Artemia* feeding was continued until metamorphosis (35 days after hatching). Juvenile coral trout were fed live tiny shrimp.

At the time of this writing, there are still a total of 195 juvenile coral trout at RIM. These fish are being used to assess the general grow-out husbandry of this species.

Figure 1.
***Plectropomus leopardus* hatchery-raised juveniles.**

Figure 2.
***Plectropomus leopardus* wild broodstock.**

1. Research Institute for Mariculture at Gondol, Bali, Indonesia. Email: gondol_dkp@singaraja.wasantara.net.id

Helping marine protected area managers cope with coral bleaching: Reef resilience toolkit

Elizabeth Mcleod[1]

Sea surface temperatures are rising and bleaching events are increasing in frequency and intensity. There is an immediate need to apply our current knowledge, albeit limited, of the ecological effects of bleaching in order to protect coral reefs worldwide. The 1998 El Niño Southern Oscillation (ENSO) event and 1999 La Niña caused mass coral bleaching of unprecedented proportions worldwide and the near complete loss of live coral at some sites. This event stimulated a major shift in planning of marine protected areas (MPA), with the concept of putting emphasis on managing coral reefs that are *resistant* to bleaching (they do not bleach) or *resilient* to bleaching (corals bleach and may die but the coral community recovers).

Coral reef scientists and conservation practitioners were previously at a loss about how to address a seemingly intractable problem: massive bleaching and mortality of corals resulting from global warming. The Nature Conservancy and partners have developed the R^2 - Reef Resilience Toolkit to help MPA managers and policymakers respond to threats from global climate change by enhancing their planning and management strategies. The multimedia, CD-ROM toolkit outlines the steps necessary to select, protect and monitor coral reef communities that are likely to be a) resistant or resilient to bleaching and/or b) sites for spawning aggregations. For maximum utility and global reach, the toolkit includes technical information, resources and tools that work with a variety of media, including television and video, computers and the Internet.

The R^2 toolkit will help practitioners begin to build resilience into their coral reef conservation programmes so that these valuable natural systems can survive anticipated global changes and provide for escalating human needs. By protecting resistant or resilient coral reef communities, MPA managers can begin implementing a strategy that aims to counter the potentially devastating impacts of climate-related coral bleaching. By protecting commercially and environmentally important spawning aggregations, marine conservation practitioners can establish refuges that harbor and safeguard important ecological processes necessary for the survival of reefs and fisheries.

The Nature Conservancy's resilience strategy includes several training workshops that will be conducted in the Asia-Pacific region and the Caribbean over the next two years. The application of resilience to field conservation programmes is a new and evolving field in which The Nature Conservancy is taking a leading role. The R^2 toolkit will be a living document, regularly updated to synthesise, interpret, and present developing resilience science in a form that is accessible to and useable by coral reef managers.

The Nature Conservancy resilience strategy

Following the release of the R^2 - Reef Resilience Toolkit, The Nature Conservancy's resilience work has shifted into a new phase of field application, testing the principles outlined in the R^2 toolkit. In developing the strategy to advance the concept and ultimately the application of resilience in the field, The Nature Conservancy determined that it was critical to have an integrated approach that includes three components: application, training and science. Application is necessary to apply the concepts and tools to MPA network design and management while building capacity for coral reef conservation and facilitating information exchange. Training is essential to share the resilience concepts and management strategies at global scales to enhance the integration of the resilience principles into coral reef management. Science provides the underpinnings of the toolkit by defining and improving the resilience principles through field testing and tracking the evolving science.

Reef managers play a crucial role in preparing for and responding to a mass bleaching; thus they need to have the tools in place to effectively handle such events. Often, reef managers working in remote areas lack the resources and skills to respond to emerging global threats. Additionally, there is a lack of scientific evidence to guide the

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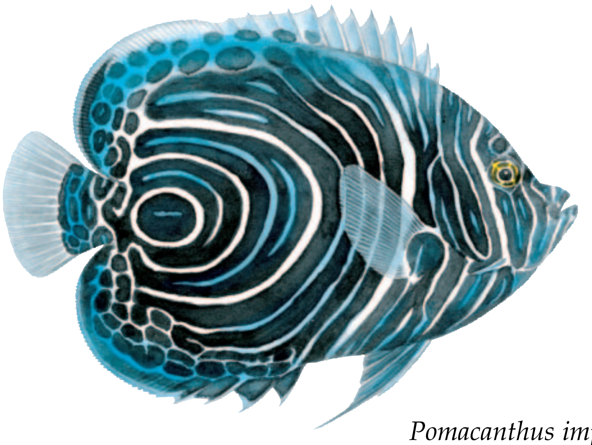
response to a bleaching event. Therefore, we need to continue to improve the science underlying the resilience principles.

In addition to improving the science underlying the toolkit, an important goal of the resilience strategy is to get the toolkit into the hands of as many practitioners as possible, establish a network of collaborating practitioners to further field test and refine the toolkit and the resilience principles, and improve the usability of the toolkit. A key element of the resilience strategy is the inclusion of both sites where The Nature Conservancy is active and other locations, where international partner organizations have a presence. An inclusive approach is essential for this effort to have far-reaching impacts and to transform coral reef conservation across the globe.

The Nature Conservancy has hired a Resilience Coordinator to provide the essential capacity that will enable the organisation to further test the resilience principles and help diminish the levels of uncertainty concerning our resilience hypothesis. Developing and refining the resislience hypothesis will help to identify and protect reefs with the greatest chance of survival.

To request a copy of the R^2 - Reef Resilience Toolkit, please contact The Nature Conservancy's Global Marine Initiative at resilience@tnc.org.



Pomacanthus imperator
Image: Les Hata, © SPC

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

PIMRIS
Pacific Islands Marine Resources Information System

News and events
live reef fish

News from SCRFA

Source: Yvonne Sadovy, SCRFA Director

The Society for the Conservation of Reef Fish Aggregations (SCRFA) has recently produced a number of reports and educational materials that might be of interest to readers. These include information pamphlets, originally in English but now also in Spanish, Chinese and Fijian. There are new reports from fishermen interviews on spawning aggregations conducted in several countries in the western Pacific, and a summary of the data collected, all available on our website (http://www.SCRFA.org). We also have a new information package that includes an easy to read handbook in an attractive format (with lots of photos) on spawning aggregation management and conservation, as well as a generic PowerPoint presentation on aggregations. Finally, we have just produced a short educational video on spawning aggregations in the Indo-Pacific. If you are interested in information or materials, please write to scrfa@hkucc.hku.hk.

Marine Ornamentals 2004

The third Marine Ornamentals conference was held 1–4 March 2004 in Honolulu, Hawaii. It was held in conjunction with Aquaculture 2004, the annual meeting of the World Aquaculture Society. For a good overview of the Marine Ornamentals conference, see the review by Doug Robbins in Advanced Aquarist's Online Magazine, March 2004, http://www.advancedaquarist.com/issues/mar2004/media.htm. The conference program and a conference summary can be viewed at the conference web site, http://www.hawaii aquaculture. org/marineornamentals04.html

Komodo fish culture project in the news

The Nature Conservancy's South East Asia Center for Marine Protected Areas is featured in a Reuters story (Dan Eaton, 1 September 2004). The Nature Conservancy's Peter Mous talks about the progress of the Center's fish culture project in Indonesia's Komodo National Park in producing groupers and other reef fish species, and its plan to become a major player in the Asian market for live reef fish. See: http://www.flmnh.ufl.edu/fish/InNews/industry2004.html

Network of Aquaculture Centres in Asia-Pacific

The Network of Aquaculture Centres in Asia-Pacific (NACA) has revamped its web site (http://www.enaca.org/). Among the many resources available on the site are the wholesale prices of live marine fish in Southern China and Hong Kong that are updated weekly, the Marine Finfish Discussion Forum, *Marine Finfish Aquaculture e-News*, and *Marine Finfish Aquaculture Network eMagazine*. The second issue of the e-magazine came out in November 2004 and featured the following articles, among others:

- Some insights into the live marine food fish markets in the region
- Farming practices, market chains and prices of marine finfish in Malaysia
- Grouper farming, market chains and marine finfish prices in Indonesia
- Marine finfish markets in Hong Kong
- Marine finfish aquaculture in China
- Assessment of the use of the use of coded wire tags to trace coral trout in the live reef food fish trade
- APEC workshop on environmental principles and policies in aquaculture administration
- Trade and market trends in the live reef food fish trade

Mariculture in the Asia-Pacific region

Source: *Marine Finfish Aquaculture e-News*, No. 15 (22 September 2004)

Mariculture in the Asia-Pacific region: Recent Developments and New Challenges, NACA will organize a special session on mariculture for the 7th Asian Fisheries Forum, (Penang, Malaysia, 29 Nov. – 3 Dec. 2004) in partnership with FAO, WFC, ACIAR, TDH and others. The session will be for one day, and combine invited presentations together with tropical mariculture papers submitted to the conference organizers.

The aspects that will be covered include the following:

- Marine farming species, including marine fish, mollusks, seaweeds
- Marine ornamentals
- Environmental management of mariculture
- Low food chain species, and integrated marine farming systems
- Marketing systems
- Consumer demand and preferences for marine aquaculture commodities
- Planning of mariculture in coastal areas
- Social aspects of marine aquaculture, and the potential for poverty reduction through mariculture

NACA extends the invitation to participate in this symposium to all researchers, the industry as well as policy makers and administrators involved in "farming the seas" of the Asia-Pacific region.

For further information contact: Dr Michael Phillips or Mr Sih Yang Sim, Network of Aquaculture Centres in Asia-Pacific, Suraswadi Building, Department of Fisheries, Kasetsart University Campus Ladyao, Jatujak, Bangkok 10900, Thailand. Fax: 66-2-561-1727. Email: grouper@enaca.org

More information on the 7th Asian Fisheries Forum can be found at http://www.usm.my/7AFF2004

MAC-industry partnership: Training for post-harvest quality control in Indonesia

Source: *MAC News*, 1st Quarter 2004

The MAC regional office in Indonesia conducted training in post-harvest quality control for 20 fishermen in Tejakula sub-district, north Bali, in February. The fishermen, who represented fishermen's associations from the villages of Les and Tembok, improved their understanding of how to reduce stress in fish during collection, holding, packing and transport through the training provided by MAC and marine biologist (and Amblard employee) Vincent Chalias. Best practices in screening, stock rejection and purging were also covered. Illustrated handouts helped the participants understand issues during classroom discussion, which was followed by a practical session in the screening and packing area. While the professional marine ornamental fishermen who participated in the training have been collecting fish for most of their lives, they had been interested in assistance to ensure they are handling the fish carefully and effectively. A second training session is tentatively scheduled for early May for another group of fishermen in north Bali.

Mariculture and Aquaculture Management (MAM) Standard under review

Source: *MAC News*, 2nd Quarter 2004

Work on the MAC Mariculture and Aquaculture Management (MAM) Standard is now well underway, with the fourth draft of the standard provided to the MAM Standard Advisory Group (SAG) in June for review. With this draft, the vast majority of the topics to be addressed by the standard have been identified, following some excellent interaction and input from the MAM SAG during the review of the third draft. A complete draft version of the MAM Standard will submitted to the MAC Board for review and comment following revision based on the June MAM SAG input.

While the MAC Standard review process strives to achieve consensus, there will be areas where this may not be possible. For example, there are differences in opinion regarding genetically modified organisms. It is the role of the MAC Board and its Standards Committee to work with the MAC Secretariat to sort through the divergence of views on these issues and develop a standard consistent with the role and mission of MAC.

More than 50 individuals worldwide are members of the MAM SAG. Additional persons wishing to join this group should submit their name and email address to mamsag@aquariumcouncil.org.

Pacific Islands update: Collector training program expands to the Pacific region

Source: *MAC News*, 2nd Quarter 2004

After attending the Training of Trainers Workshop in the Philippines in late March–early April 2004, MAC Pacific Trainer Chris Beta and MAC Pacific Resource Management Officer Gregory Bennett began the first training session for Pacific Island collectors in Fiji in June. Six collectors from one company were trained in harvest and post-harvest handling practices that are compatible with the MAC Collection, Fishing, and Holding (CFH) Standard. From this training session, needed improvements in certain practices were identified for the company to follow up on. Training has been planned for new collectors at another company, which will include making and repairing collection equipment and species identification. Collector training is also being planned for the Solomon Islands, Tonga and Kiribati.

In Vanuatu, one exporter is being assisted by MAC to comply with the MAC Standards. MAC also shared information on the Marine Aquarium Trade Coral Reef Monitoring Protocol (MAQTRAC) and equivalent resource assessment methodologies with the Secretariat of the Pacific Community (SPC) during a visit to Vanuatu in May 2004. Information on the MAQTRAC survey conducted in Vanuatu in February 2004 will assist the industry and the Fisheries Department with management of the aquarium industry as part of their interest in MAC Certification. For more on MAQTRAC, see http://www.reefcheck.org/management/MAT.asp.

MAC is assisting two Tongan exporters to understand and achieve compliance with the MAC Standards and will be working with stakeholders to develop collection area management plans (CAMPs) for Tonga collection sites later in the year. In addition, collaborative efforts are being made by all stakeholders to develop a National Aquarium Fishery Management and Development Plan for Tonga.

MAC continues to work with villagers in the Solomon Islands. Collector training is scheduled to begin in July 2004, and plans are underway to develop CAMPs for two collection areas.

MAC Pacific efforts continue in Fiji, Tonga and Solomon Islands

Source: *MAC News*, 3rd Quarter 2004

MAC is completing work with one company and beginning work with two other companies and their communities in Fiji to achieve compliance with MAC Standards. The development of collection area management plans (CAMPs) has begun for the sites used by the two new companies.

MAC is also working with a range of stakeholders in Fiji on issues such as the sustainability of coral and live rock collection. In July, MAC participated in a workshop on "Fiji's Non-detriment Finding Methodology for Extraction of and Trade in Marine Aquarium Species" to which international representative were invited. MAC's Executive Director Paul Holthus attended the meeting, as well as MAC Pacific Program staff and Reef Check Director Gregor Hodgson, PhD.

Elsewhere in the Pacific, MAC collector trainer Chris Beta is working with three companies in Tonga, and CAMPs for Madou and Rarumana in the Western Province of the Solomon Islands will be initiated towards the last quarter of the year.

Pet industry and government resource agencies unite to create a new "Habitattitude" on aquatic invasive species

Source: *MAC News*, 3rd Quarter 2004

The Pet Industry Joint Advisory Council (PIJAC), a co-founder of MAC, has joined with federal agencies to help consumers prevent the release and escape of non-native plants and animals through Habitattitude', a new public education and outreach effort. The government-industry coalition is formed from PIJAC, the US Fish and Wildlife Service, the National Oceanic and Atmospheric Administration and Minnesota Sea Grant. Habitattitude' encourages aquarium owners to avoid unwanted introductions of non-native species by adopting simple prevention steps when faced with an unwanted aquatic plant or fish:

- Contact a retailer for proper handling advice or for possible returns.
- Give/trade with another aquarist.
- Donate to a local aquarium society, school or aquatic business.
- Seal aquatic plants in plastic bags and dispose in the trash.
- Contact a veterinarian or pet retailer for guidance on humane disposal of animals.

"Beginning this fall, when aquarium hobbyists go to purchase fish or plants for their tanks or ponds, they'll receive the Habitattitude' message," said Marshall Meyers, PIJAC Executive Vice President and General Counsel. Habitattitude' materials will be displayed in aquarium stores, aquatic retail outlets, hobby magazines and nursery and landscape businesses across the country, as well as on packaging of related products.

A new Website, http://www.habitattitude.net, will help consumers to learn more about responsible behavior and how to prevent the spread of potential aquatic nuisance species. The site includes information on the U.S. federal and state laws and statutes that regulate the aquatic organisms, recommended alternatives to releasing plants and animals, instructions on how individuals and clubs can get involved and detailed information on some of the more problematic aquarium species that have created problems with aquatic ecosystems.

Noteworthy publications
live reef fish

Bellwood, D.R., Hughes T.P., Folke C. and Nyström M. 2004. Confronting the coral reef crisis. Nature 429:827–33. Abstract: http://www.nature.com/cgi-taf/DynaPage.taf?file=/nature/journal/v429/n6994/abs/nature02691_r.html&dynoptions=

Cato, J.C. and Brown C.L. (eds.) 2003. Marine ornamental species: Collection, culture and conservation. Blackwell Publishing. 448 p.

Kao, Chen-Chih. 2004. Development of grouper culture in Taiwan – a solution to reduce destructive fishing practices in coral reefs. INFOFISH International, Number 3/2004.

Larkin, S.L. and Adams C.M. 2003. The marine life fishery in Florida, 1990–98. Marine Fisheries Review 65(1):21–31.

Lunn, K.E. and Moreau M.-A. 2004. Unmonitored trade in marine ornamental fishes: The case of Indonesia's Banggai cardinalfish (*Pterapogon kauderni*). Coral Reefs 23:344–351. http://www.springerlink.com/index/10.1007/s00338-004-0393-y

Ottolenghi, F., Silvestri C., Giordano P., Lovatelli A. and New M.B. 2004. Capture-based aquaculture: The fattening of eels, groupers, tunas and yellowtails. Rome: United Nations Food and Agriculture Organization. 332 p.

From the publisher, the UNFAO: "Capture-based aquaculture" defines and reviews certain practices that are shared between aquaculture and capture fisheries. It specifically considers the on-growing or fattening of four species groups — eels, groupers, tunas and yellowtails — which is based on the use of wild-caught "seed". The report begins with an introduction on the overlap between aquaculture and fisheries and their global trends. Chapters on the four species groups follow and include information on species identification, fishery trends, the supply and transfer of "seed" for stocking purposes, aquaculture trends, culture systems, feeds and feeding regimes, fish health, harvesting and marketing. Further chapters examine the environmental and socio-economic impacts of capture-based aquaculture, together with the relevant fisheries and aquaculture management issues. Finally, the report looks at food safety issues, as well as identifies topics for future consideration. The principal targeted audience includes policy-makers, administrators and trainers in the fields of aquaculture, fisheries and the environment.

Pomeroy, R.S., Agbayani R., Duray M., Tooledo J. and Quinito G. 2004. The financial feasibility of small-scale grouper aquaculture in the Philippines. Aquaculture Economics & Management 8(1–2):61–83.

Sadovy, Y.J., Donaldson T.J., Graham T.R., McGilvray F., Muldoon G.J., Phillips M.J., Rimmer M.A., Smith A. and Yeeting B. 2003. While stocks last: The live reef food fish trade. Manila, Philippines: Asian Development Bank. http://www.adb.org/Documents/Books/Live_Reef_Food_Fish_Trade/default.asp

From the publisher, ADB: Live fish have long been traded around Southeast Asia as a luxury food item. Fish captured on coral reefs entered this trade only in recent years but, because of their superior taste or texture, have become the most valued fish in the trade. This book is the result of the work by nine independent scientists who agreed to contribute their time to write on specific topics within their individual expertise on live reef food fish (LRFF) trade issues. The picture that emerges from this book is extremely worrying: the LRFF trade has caused degradation of the resources on

which the trade depends, and hence has to move farther and farther from the main market centers in order to continue to supply them. The book provides scientific evidence for the need to curb and manage the capture of wild live reef food fish, and proposes ways to help entrepreneurs and fishers reform the trade based on limiting fish capture and hatchery rearing the fish.

Stiassny, M.L.J. 2004. Saving Nemo: Aquariums, once water-filled cabinets of curiosities, exert potent economic forces that can foster conservation in the wild. Natural History Magazine, March 2004. http://www.naturalhistorymag.com/0304/0304_feature.html

SPC *Live Reef Fish* activities online

The first 13 issues of this bulletin, as well as many other publications from the SPC Coastal Fisheries Programme, are available on SPC's website at: **http://www.spc.int/coastfish/**

An email discussion group has been set up at SPC to provide a more immediate way of exchanging news and information between members of the Live Reef Fish network, and to enable faster responses to issues. To subscribe, send a blank message to: **join-live-reef-fish@lyris.spc.int** or go to: **http://lyris.spc.int/read/all_forums/subscribe?name=live-reef-fish**

To view recent messages from the list, check the following Internet address: **http://lyris.spc.int/read/?forum=live-reef-fish**

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