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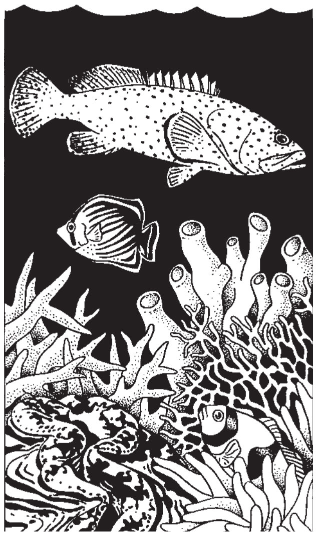
South Pacific Commission

LIVE REEF FISH

The live reef fish export and aquarium trade

Number 3 — December 1997

INFORMATION BULLETIN



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Editor's mutterings

Statistics

There has been a major upswing in support for measures to put the live reef fish trade on a sustainable basis. WWF, TNC, IMA, USAID, ADB, NACA, WRI and a variety of other acronymous NGOs and aid agencies have thrown their support behind the effort, and this publication continues to describe their work. But how successful are we?

We know that a few battles have been won at local levels, such as the line fishing cooperative at Canipo Island in the Philippines (see Barber & Pratt, p. 26). But we have no idea if we are winning or losing the overall war. A major problem is the difficulty of getting good statistics.

The biggest gap in our statistics is our almost total ignorance of the trade in China. Hong Kong importers say that mainland China is presently vying with Hong Kong as the biggest importer of live reef fish in the world, but we have no statistics with which to confirm this.

China may also be the largest grouper farming country in the world, but I have been unable to get any details concerning species, sources of wild-caught juveniles, the extent, if any, of commercial hatchery-based production, etc. Any information readers might supply on any of these subjects would be gratefully received and passed on to readers.

We also have no statistics for internal consumption of live reef fish in South-East Asian countries. Yet there is a sizeable, wealthy Chinese population in most of them, with a taste for live reef fish.

(continued on page 2)

Inside this issue

Observers in the Philippines and Indonesia say that foreign live reef-fish transport vessels often enter their waters, load up with live fish, and leave without registering their presence or activities officially (see, for example, Erdman & Pet-Soede, p. 41). Export statistics from these countries naturally do not include these fish. Since, in the Philippines, all fish shipped out through official channels will now be checked for cyanide (see Barber & Pratt, p. 26) there is now an increased incentive to ship fish out surreptitiously by this method.

The authorities have proven unable to stop this illegal export in either country. One of the two main reasons is the shortage of manpower and suitable vessels for surveillance and enforcement. The other is corruption.

Corruption

It is no secret that corruption among government officials and the military is rampant in Indonesia. Laws and regulations are often obstacles only for those unable to pay. Herman Cesar of the World Bank estimates that 6.7 per cent of the direct costs of cyanide fishing in Indonesia go for 'side-payments'—a quaint World Bank euphemism for bribes. Of how much value are improved laws and regulations under such circumstances?

At least as recently as late 1996, humphead wrasse in excess of the maximum legal size in Indonesia were arriving in Hong Kong in large numbers in live reef-fish transport vessels bearing export permits signed by Indonesian officials (V. Pratt, pers. comm.).

Similar corruption is also widespread in the Philippines (e.g. Barber & Pratt, p. 26), although, to its credit, the Ramos government is making a more serious effort to control it. (The humphead wrasse problem in Indonesia may 'solve' itself fairly soon, as it has already in the Philippines. The reefs of the latter country seem to have been virtually denuded of mature humphead wrasse by the live reef-fish trade. Large, sexually mature fish were common in export shipments monitored by the International Marinelife Alliance prior to 1997. Now none are seen (V. Pratt, pers. comm.).

Twenty years ago corruption was not a major problem in the Pacific Islands. But times are changing. The newspapers in the region are full of accounts of government corruption and bribery. The logging industry is an especially flagrant example. Here foreign companies, most of them from South-east Asia, bribe their way into lucrative logging deals and leave the forests ravaged, traditional forest owners desolated, and certain politicians smiling all the way to the bank.

There is little publicity, as yet, concerning similar deals being made in connection with the much more recently introduced live-reef food fishery. But the new gold rush has begun, venture capital is plentiful in the main countries involved in these operations, and the resource pirates are gathering. There is thus no reason why reef resources will not, like forest resources, be sacrificed wholesale to greed, unless government vigilance is much greater than it has been in the case of logging.

There are some principled people in the live reef-fish industry, to whom the foregoing comments do not apply. But the record of the industry as a whole is so bad that such people will, unfortunately, have an uphill battle to prove their good intentions (and possibly an even bigger battle to survive the unprincipled actions of their competitors).

What else can we learn from the sad experiences of logging in the Pacific Islands in the past decade?

One thing is that, if governments allow unsophisticated traditional fishing-rights owners to negotiate live-fishery agreements directly with foreign companies, the latter will be grossly disadvantaged. They will run a high risk of being ripped off, just like traditional Pacific Island land owners in their dealings with foreign logging companies.

Another is that well-constructed permits for live reef fishing operations with sound safeguards written into them (see Smith, p. 47), are of little value if governments do not act promptly to punish or ban those companies who violate their permit conditions.

A third is that violations of indigenous land rights by logging companies often proved to be easy; it will be even easier to violate indigenous fishing rights when the resources and the activities that destroy them are both out of sight beneath the surface.

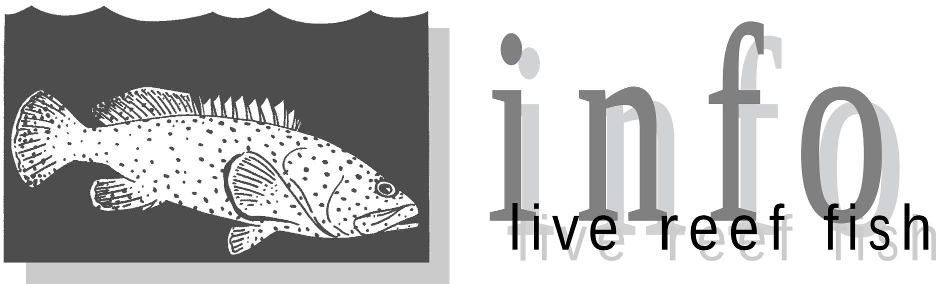
Island governments should allow no one but their Fisheries Departments to negotiate contracts directly with foreign live-fishing companies. If they do, they run a high risk of contracts highly disadvantageous to the country, both economically and environmentally. Such contracts can be (and in at least one case, have already been) rushed through before anyone with a proper understanding of the issues and threats had a chance to review them.

To be sure, fisheries departments are not always free of political or economic pressure to turn a blind eye to destructive fishing. But the chances of it happening are reduced when they are helped to become aware of the issues (see Smith, p. 47) and are the sole agencies for licensing live reef-fishing operations. And if it does happen, the search for those who allowed it to happen is greatly narrowed.

In 1993, the Secretary to the Department of Fisheries and Marine Resources in Papua New Guinea stated that he had been offered, and turned down, a total of US$ 23,000 in bribes (Anon. 1993. Fisheries 'Bribes' in PNG. South Seas Digest 13: 7, 18 June). We commend such behaviour, as well as that of island officials who have enforced restrictions or rejected unsatisfactory applications despite considerable pressure. We know of several islanders who have been, or still are, taking considerable heat for their stands. We can be pretty sure, however, that pressures or inducements are being brought to bear on other Island officials, and that not all of them will be this principled.

It is governments with whom the primary responsibility lies for ensuring sustainable use of their countries' renewable natural resources. The ultimate blame for destructive live reef-fishing practices thus lies more with governments that do not make serious efforts to regulate the industry, than with the industry itself. Aid donors might consider shifting their aid for fisheries from such countries to those with more responsible governments.

R.E. Johannes



Effects of cyanide on coral (1)

by Dr Ross J. Jones [1]

Bold numbers in brackets relate to references listed at the end of the article.

Cyanide is used on coral reefs to collect tropical aquarium fish and to supply a rapidly growing restaurant-based demand for live reef fish in South-East Asia **(22)**. To examine potential environmental effects of cyanide fishing on corals, small fragments of the hard coral *Pocillopora damicornis* were subjected to a range of cyanide concentrations for different exposure times. Corals died following the highest doses; lost their symbiotic algae (zooxanthellae), resulting in a discolouration or 'bleaching', at medium doses; and at lower doses lost zooxanthellae, but not in sufficient numbers to physically discolour. Respiratory rates of *P. damicornis* were measured with a coral respirometer. Respiratory rates were inhibited by 10–90 per cent following exposure to various cyanide doses but recovered to pre-exposure levels within 1–2 h of being transferred to clean seawater. These results are discussed in relation to doses likely to be experienced by the corals as a result of cyanide fishing.

All experiments were conducted at One-Tree Island (23°30'S, 152° 06'E), Great Barrier Reef, Australia in November 1995. Small fragments of *Pocillopora damicornis*[2] were exposed to 10, 1, 0.1, or 0.01 part per thousand (ppt; $g \bullet l^{-1}$) cyanide

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2. 15 colonies of *Pocillopora damicornis* (brown ecomorphs) **(22)** were collected from 1–2 m depth in the lagoon at One-Tree Island reef. 100 small coral fragments (40 40 mm) were cut from the colonies (5–10 fragments per colony) and their bases then inserted into small acrylic tubes to provide support. All corals were placed in running seawater for 3–4 h prior to the experiments.

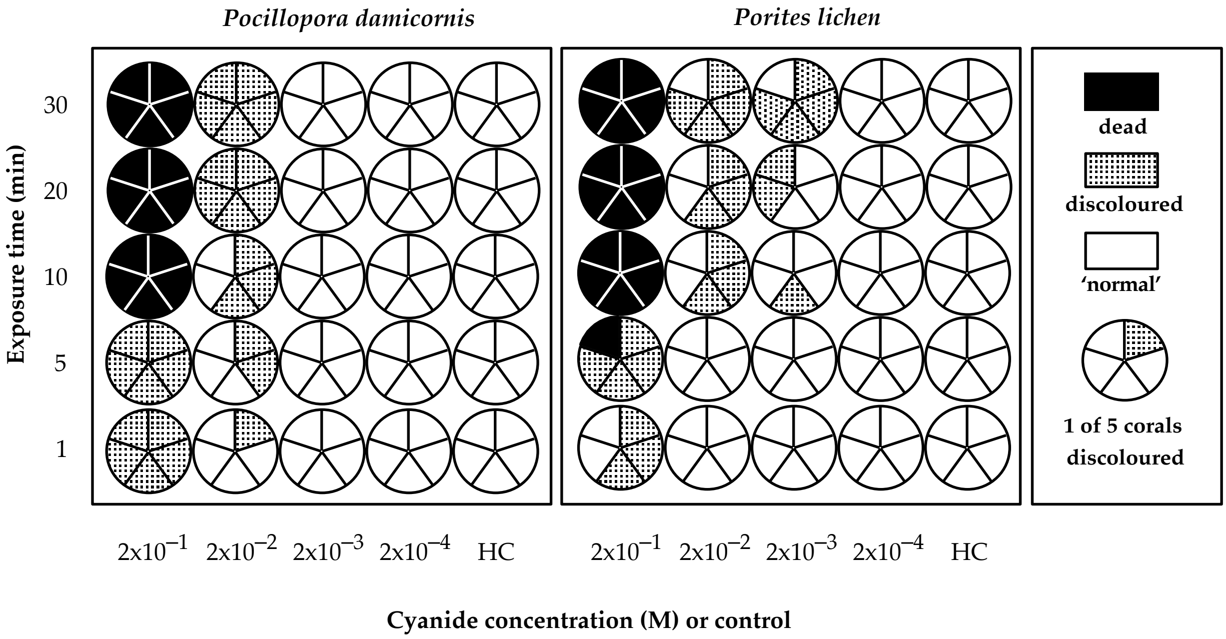

Figure 1

Mortality and visual assessment of discolouration in 5 fragments of *Pocillopora damicornis* 6 days after exposure to cyanide solutions (2×10^{-1}, 2×10^{-2}, 2×10^{-3}, 2×10^{-4} M for 1, 5, 10, 20 or 30 min). Colonies were classified as discoloured if they appeared a pale brown or white colour. HC = Handling Controls (see Fig. 2 text).

(nominal concentrations), for either 1, 5, 10, 20 or 30 min[3]. Corals exposed to 10 ppt cyanide for longer than 10 min died within 24 h (Fig. 1). At shorter exposure times and at lower cyanide concentrations, the corals changed from a normal brown colour to a pale brown or white colour. The intensity of discolouration was dependent upon cyanide concentration and duration of exposure, to cyanide (Fig. 1).

The discolouration observed in these studies is referred to as coral 'bleaching'. Corals gain most of their brown colouration from the photosynthetic pigments of the symbiotic algae (zooxanthellae) in their tissues. When corals bleach, either they lose zooxanthellae **(3)**, or the zooxanthellae lose their pigments **(4)**, or both **(5)**. To determine the nature of the bleaching, the density of zooxanthellae and the chlorophyll concentration of the zooxanthellae in the corals were determined[4]. Discoloured colonies had only 10–40 per cent of the zooxanthellae in control corals (Fig. 2). There were no decreases in algal chlorophyll-a concentrations (data not shown). The results indicate that the cyanide exposure caused a dissociation of the coral-algal symbiosis.

Loss of zooxanthellae is a common stress response of corals to abnormal environmental conditions **(6)**. Bleaching has been observed in corals exposed to quinaldine, a fish-collecting chemical **(7)**; toxic secondary metabolites of soft corals **(8)**; heavy metals **(9, 10)**; depressed seawater temperature **(11);** and elevated seawater temperatures **(12)**. Loss of zooxanthellae is an ecologically significant response resulting in a loss of phototrophic potential **(5)**, cessation or reduction of growth **(5, 13, 14, 15)** and a decrease in reproductive output **(16)**. However, loss of zooxanthellae can be a sublethal response. There are numerous observations of recovery of zooxanthellae and pigmentation by bleached corals **(3, 5, 17)**. The time taken for corals to fully

3. Cyanide solutions were prepared immediately before each experiment using freshly collected unfiltered seawater. Solutions were stirred with a magnetically coupled spin bar before and during experiments. 5 replicate coral species were randomly selected from the pool of prepared coralsa and placed in 1 l of the incubation medium. After incubation corals were transferred to an aquarium receiving a supply of running seawater for 15–20 min, then secured to an acrylic tray at 1–2 m depth on the reef. Corals were examined for mortality, general health and appearance for up to 12 days following incubations. They were then frozen prior to determining the algal densities and chlorophyll concentrations.

4. Tissues were stripped from the corals using a jet of recirculated 0.45 μ membrane-filtered seawater. Zooxanthellae density in the resulting tissue homogenate was estimated using a hemacytometer (8 replicate counts) and algal chlorophyll-a concentrations were estimated by solvent extraction (90% acetone) and measured spectrophotometrically**(4)** .

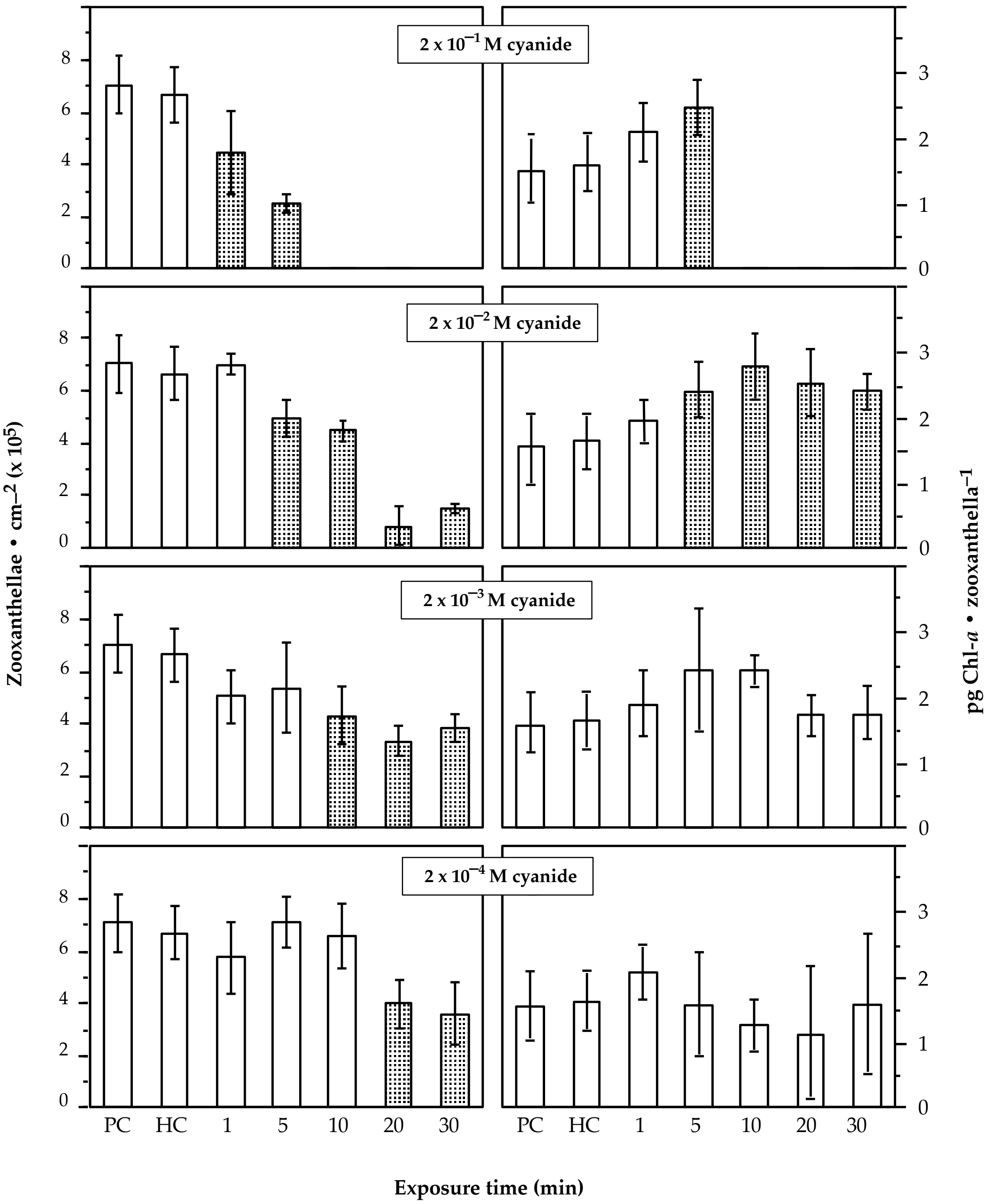

Figure 2

Zooxanthellae density (• 10^5 zooxanthellae cm^{-2}) in fragments of *Pocillopora damicornis* 12 days after exposure to various doses of cyanide. PC = 'Parent Colony' controls, i.e. corals randomly selected from the pool of prepared corals and frozen prior to the toxicity tests. HC = 'Handling Controls', i.e. corals exposed to an ambient seawater solution alone for 30 min during the toxicity experiments. Data are presented as ±95% confidence intervals, n = 5 corals. Dunnett's test of significance was used to compare the nature of significant differences by comparing treatment and control (HC) means. Significant differences are indicated by shading. Prior to all analysis assumptions of normality (Shapiro-Wilks' test) and homogeneity of variance (Welch's test) were tested.

recover from loss of zooxanthellae observed in these studies may take between six months and one year **(9, 17)**.

Assessment of coral discolouration (Fig. 1) did not correlate with measured decreases in zooxanthellae density (Fig. 2). For example, corals exposed to 0.1 ppt cyanide for 10, 20 and 30 min, and 0.01 ppt for 20 and 30 min had significantly lower zooxanthellae than control corals, but there was no obvious discolouration of the corals. The results suggest that corals can lose 40–60 per cent of their zooxanthellae without physically discolouring. Similarly, colonies of a staghorn coral *Acropora formosa* which lost 40–50 per cent of their zooxanthellae during a thermally related bleaching event also did not discolour **(9)**. Corals may therefore be suffering from stress-related loss of algal symbionts both in the field and in laboratory manipulations without any gross observable effect. This must be taken into account when interpreting results from reef surveys conducted after cyanide fishing or from future experiments exposing corals to cyanide.

The effect of cyanide on coral respiration was measured using a 4-chamber coral respirometer **(18)**. The respiratory rates of small fragments of *Pocillopora damicornis*[5] were determined before and after exposure to 5 ppt, 1 ppt and 0.1 ppt cyanide for 2.5 min, 5 min and 7.5 min[6]. Corals survived the experiments, despite respiratory rates in some being inhibited by 80–90 per cent (Fig. 3). The time taken for the corals to return to pre-dosage respiratory rates varied from 0.5 h to >1.5 h dependent upon cyanide concentration and exposure time.

To relate the toxicity studies (Fig. 1 and 2) to conditions occurring during cyanide fishing I have employed a technique used to estimate the effects of crude and chemically dispersed oil on marine organisms **(19)**. Cyanide concentration (ppt) is multiplied by the exposure time (min) to yield a cyanide dose in 'ppt-min' cyanide, i.e. 10 ppt for 30 min = 300 ppt-min (the highest cyanide dose tested). Cyanide dose is then related to mortality and zooxanthellae density (Fig. 4). Corals exposed to doses equal to or greater than 100 ppt-min cyanide died. Below a dose of 0.2 ppt-min no significant algal loss occurred. Between these doses various degrees of algal loss occurred (Fig. 4).

During cyanide fishing, corals are likely to experience initially high (ppt) concentrations of cyanide which fluctuate rapidly, but ultimately dilute to very low (ppb; parts per billion) levels in periods of time ranging from seconds to hours. The starting cyanide concentration, proximity to target fish and local hydrological conditions will determine the dose (as ppt-min) experienced by corals.

The cyanide concentration in a cyanide fishermen's squirt bottle has been estimated as approximately 20 ppt **(2)** . If we consider a situation in which a coral thicket is exposed to cyanide immediately from a squirt bottle and the cyanide concentration then halves every minute thereafter (i.e. decreasing to 2 ppb concentration in ≈ 25 min), the coral will be exposed to a total cyanide dose of 40 ppt-min cyanide (i.e. the sum of 20 ppt for 1 min, 10 ppt for 1 min, 5 ppt for 1 min, etc). Under a logarithmic decrease in cyanide concentration (i.e. decreasing to 2 ppb in ≈ 8 min), the coral will be exposed to 22 'ppt-min' cyanide. In both scenarios the dose of cyanide experienced by coral should result in significant loss of zooxanthellae, given the results of the toxicity tests (Figs. 2 and 4).

In practice, accurately estimating the dose of cyanide experienced by corals during cyanide fishing is impossible. Nevertheless, if we recognise that high (ppt) concentrations of cyanide are used during cyanide fishing, and that loss of zooxanthellae from corals can occur after only very short (1 min) exposures to cyanide (Fig. 2), the results of this study suggest a deleterious effect of cyanide fishing on corals in the immediate vicinity.

Pockets of dyed water have been observed trapped in a stagnant zone behind a large (1 m diameter) coral head for 30 min **(20).** Under such conditions, and also during the more destructive fishing techniques such as pumping cyanide from surface boats **(21)** coral mortality may be extensive.

It has been assumed in these experiments that corals which were not dead 12 days after cyanide exposure (Figs. 1 and 2) would ultimately survive. This has not been ascertained to my satisfaction. An examination of the long-term survival of corals following cyanide exposure, and the longer-term effects of low-level (chronic) cyanide exposure (not included in these experiments), is clearly warranted.

5. Experiments were conducted using large fragments (60 x 60 mm) of *Pocillopora damicornis* colonies cut from 12 individual colonies (1–2 m depth) in the One-Tree Island lagoon.

6. During incubations, oxygen concentrations were logged every 20 s, and every 20 min the chambers were flushed with fresh seawater for 2 min to prevent the oxygen concentrations from falling below 75% saturation. During incubation, a black cloth was draped over the chambers to reduce light levels to <1 $\mu E \bullet m^{-2} \bullet s^{-1}$. Water temperature during each of the incubations was 26°C ± 1°C.

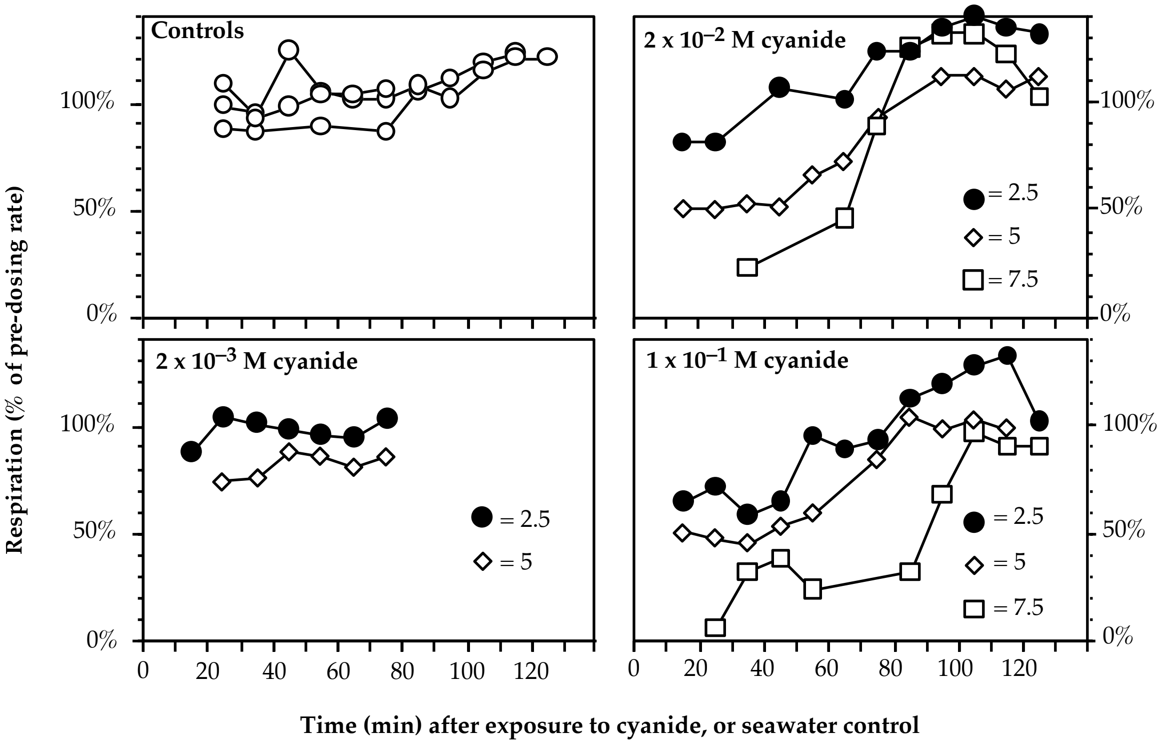

Figure 3

Respiratory oxygen consumption in fragments of *Pocillopora damicornis* after exposure to 5, 1 and 0.1 ppt cyanide solution for 2.5, 5, and 7.5 min or control (ambient seawater) for 7.5 min, n = 1 for each line plot. Respiratory rates are expressed, relative to the mean respiration rate determined for each coral over a 1–2 h period before cyanide exposure (see footnote 6).

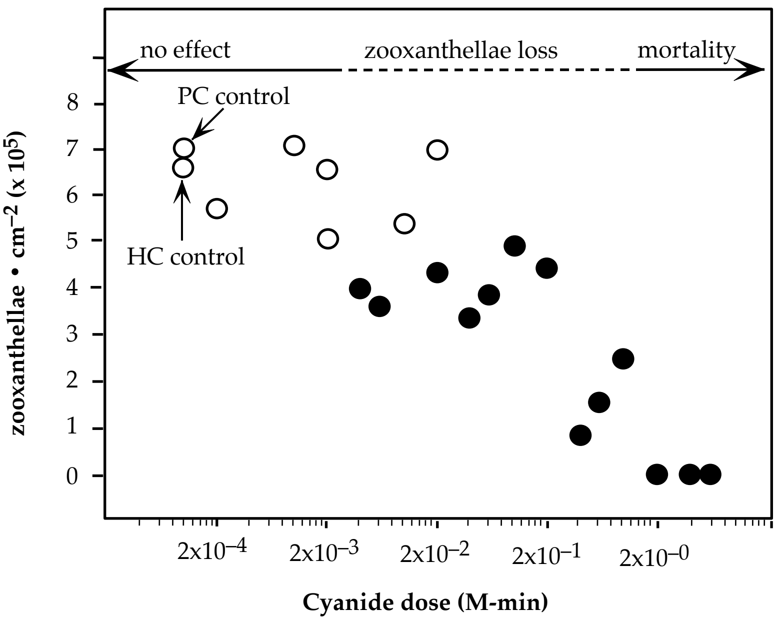

Figure 4

The relationship between the cyanide dose and mortality/zooxanthellae density in colonies of *Pocillopora damicornis* 12 days after exposure to various cyanide doses. Each point represents the mean of 5 corals. 'C' denotes the HC and PC controls (see Fig. 2 text). The filled symbols represent significant differences in algal densities relative to control (HC) explants (ANOVA, P<0.05, see Fig. 2).

In summary, the inadvertent exposure of corals to cyanide during cyanide fishing is likely to result in a reduction or cessation of respiration. The most obvious response of corals appears to be the dissociation of the coral-algal symbiosis, resulting in discolouration or bleaching. The ecological consequences of the dissociation are known: a reduction in phototrophic potential, a decrease in growth rates and a decrease in fecundity. Re-establishing the symbiosis may take from six months to one year or more.

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Bahrain fish stock enhancement: lessons learned and prospects for the future

by K. Roger Uwate & Abdulredha J. Shams [1]

Introduction

Stock enhancement

The concept of increasing or re-establishing fish and invertebrate populations through ocean ranching has been considered for many years (Kafuku, 1986; Yamaguchi, 1988).

Results from stock enhancement programmes have varied. In Japan, 8 per cent of 206,000 tagged red seabream were recovered (Cowan, 1981). For blue crab, the recapture rate was 22 per cent. By the early 1980s, Japan had been involved in stock enhancement for about 15 years with annual expenditure reaching about US$ 40 million (Preston & Tanaka, 1990). However, results were still inconclusive. In many cases, there was no demonstrable effect on harvest, despite years of restocking efforts.

In Norway, cod stock enhancement studies resulted in survival rates from 13 to 32 per cent (Svaasand & Kristiansen, 1990b). Released cod represented between 21 and 61 per cent of the entire cod population of a fjord (Svaasand & Kristiansen, 1990a).

There are several key issues when a stock release programme is being considered (see Preston & Tanaka, 1990; SPC Secretariat and the FAO South Pacific Aquaculture Development Project, 1990; Naevda & Joerstad, 1983; and Thorpe, 1986):

1. Stock enhancement is not a substitute for fisheries management;
2. Knowledge of the biology and culture technology of a species is critical to the success of stock enhancement;
3. The impacts of stock enhancement programmes may be insignificant or can be extremely difficult to assess;
4. Stock enhancement programmes can affect the gene pool of wild stocks;
5. There can be complications when exotic species are introduced as part of any stock enhancement programme;
6. Stock enhancement programmes can be very costly and absorb major resources.

Bahrain fisheries situation

Overall fish landings have fluctuated over the years, but the situation appears to be rather stable (Fisheries Statistical Service, 1996). However, landings and catch-per-effort estimates for certain preferred species suggest that these resources are being overfished. This is especially evident with species such as grouper, shrimp and Spanish mackerel.

The major difficulty in Bahrain's fishery is the level of illegal fishing (Directorate of Fisheries, 1993). Regulations are in place, but enforcement of regulations and compliance have been negligible.

National Mariculture Center (NaMaC)

Hatchery technologies are currently being developed and refined at the National Mariculture Center (NaMaC) at Ras Hayan (Shams & Uwate, 1996). Species undergoing hatchery and grow-out trials include: grouper (hamoor), *Epinephelus coioides*; two species of seabream (shaem), *Acanthopagrus latus* and (sobaity) *Sparidentex hasta*; and rabbitfish (saffee), *Siganus canaliculatus*. NaMaC fish fry production between 1994 and 1996 is presented in Table 1.

Grow-out capacity of NaMaC is limited. Starting in 1994, hatchery production exceeded grow-out requirements. This provided the resources necessary to initiate trial fish releases.

1. National Mariculture Center, Directorate of Fisheries, Ministry of Works and Agriculture, State of Bahrain

Table 1: Number of fingerlings released in Bahrain, 1994–1996

Year	Fry produced		
	Grouper *Epinephelus coioides*	Rabbitfish *Siganus canaliculatus*	Seabream *Acanthopagrus latus*
1994	31,400	4,000	17,000
1995	11,000	59,000	0
1996	12,000	59,000	120,000
Total	**54,400**	**122,000**	**137,000**

Table 2: Number of fish released in Bahrain, 1994–1996

Year	Nos of fingerlings released		
	Grouper *Epinephelus coioides*	Rabbitfish *Siganus canaliculatus*	Seabream *Acanthopagrus latus*
1994	10,000		7,000
1995	10,000	300	3,000 *
1996	8,250		116,000
Total	**28,250**	**300**	**126,000**

* fish produced in 1994 and kept over winter prior to release

Bahrain fish releases

1994

The objective of the 1994 fish-release efforts was to develop and refine procedures for future large-scale fingerling releases (see Uwate & Al-Ansari, 1994). Youth volunteers completed pelvic fin clips on 7,000 seabream (shaem) and 8,000 grouper (hamoor). In 1994, fish were transported by towed barge in 1 tonne fibreglass tanks with oxygen aeration. About 17,000 fish were released in 1994 (Table 2).

Several key issues became apparent during 1994 fish-release trials (Uwate & Al-Ansari, 1994): (1) fish releases should be completed when water temperature is not extreme (not above 35°C); (2) outboard engines broke often when speedboats were used to tow the barge; (3) transport of 1,000 fingerlings with a 1 tonne aerated fibreglass tank resulted in almost 100 per cent survival; and (4) public cooperation was critical to the success of this project.

Interestingly, in 1994 the Directorate of Fisheries received informal reports that some fishermen were actually catching and selling large quantities of grouper fingerlings to the consumer market. This was done despite a media campaign during fish releases.

1995

The 1995 fish-release objective was to demonstrate that fish releases can be routinely accomplished by the Directorate of Fisheries (Uwate et al., 1996). Observations of 1994 fin-clipped fish indicated that fins grew back in four to six months. In 1995 youth volunteers tagged 3,000 shaem with plastic anchor tags. Since grouper prefer caves and rocky areas (where tags could catch), groupers were not tagged. A total of 13,300 fish were released in 1995 (Table 2).

Lessons learned in 1995 (Uwate et al., 1996) included: (1) truck transport and release was quick, but bucketing fish from the truck to the sea was difficult and hazardous; (2) boat and barge transport was more reliable when lower boat speeds were used; and (3) public cooperation was again very helpful in the success of 1995 releases.

1996

In 1996, the objective of fish-release activities was to refine technology and demonstrate that large-scale fish releases could be completed by the Directorate of Fisheries (Al-Hendi et al., 1996). The quantity of fish released in 1996 was almost 10 times that moved in previous years (Table 2). Fish were not marked in 1996 because: (1) there was no budget for fish release; (2) time available for release was very short; and (3) facilities and resources (feed, water, manpower) for fish grow-out were extremely limited.

As in the past, public cooperation was very helpful in completing this project (Al-Hendi et al., 1996). For two of the grouper releases, a private boat was used (at no government expense). Most of the fish releases were done using a six-wheel truck. The problems of releasing fish by bucket were overcome by attaching one or two 6 in diameter PVC pipes to the flex hose on the truck tanks. Fish could then be flushed directly into the sea.

Effects on landings

One key question about any fish-release programme is: does it increase fish stocks and fish-landings? Since there has never been any project budget for fish releases, modern fish tagging technology could not be applied. The Directorate of Fisheries routinely sends staff to record fish landings (for its annual statistics report). Some anecdotal reports have been received of large quantities of small grouper and shaem entering the market just after fish releases .

More recently, a model for grouper landings was proposed and constructed (Radhi, draft). Linear and quadratic time-series analyses were completed applying the multiplicative decomposition model (including seasonal, trend, cyclical, irregular components). The quadratic time-series model generated closely resembled grouper landings from 1980 to 1994. Thus it was considered a good model.

Since fish releases started in mid-1994, a six-month delay was assumed prior to impact of released fish (Radhi, draft). Using the above model, landings for January 1995 to June 1996 were projected and were compared with actual landings (from the Fisheries Statistical Services database). For this post-release period, actual grouper landings were always higher than those projected by the model. This suggests that for grouper release, there has been a positive impact on the fishery, epecially, on landings.

Costs and benefits

Another critical issue for any fish-release programme is: how do the costs of the programme compare with the benefits? It is not appropriate if it costs $ 10 to grow and release a fish, which is harvested and sold for $ 5.

Prior to initiating a fish-release project, it is possible to estimate costs and benefits. Production and fish-release costs can be reasonably estimated based on hatchery experiences and appropriate budgets for transporting fish.

However, estimating the benefits of fish releases is very difficult. Even with sophisticated fish marking and landing surveillance, it is difficult to detect effects of increased landings, let alone quantify benefits. What is the value of the additional fish? Is it based on the landed or retail market price? the value of a recreationally caught fish? the value to the local economy? or a societal value? As noted above ('Stock enhancement'), even some large stock-enhancement programmes have yet to show any impact or benefits.

In Bahrain, there has never been any additional or supplemental funding for the fish-release programme. In addition, until 1995, there were no additional funds available to operate the National Mariculture Center. NaMaC and fish-release costs were all supported by the internal annual budget of the Directorate of Fisheries. This budget has been stable for the last few years. The only way these major activities have been supported has been by reallocation of resources within the Directorate of Fisheries and by more efficient utilisation of existing resources.

As additional large-scale fish releases are completed in Bahrain and effects to the fishery are measured and documented (as in Radhi, draft), it will be possible to quantify and value the economic benefits of the Bahrain fish release programme.

Discussion

Over the last few years, NaMaC has demonstrated that it can mass-culture key fish species. In addition, the Directorate of Fisheries has demonstrated that it can transport and release fish anywhere in Bahrain and its adjacent waters. Fish mortality during transport is very low, in most cases zero. Public support, in the form of volunteers, has been extremely valuable in achieving success with this project.

Like artificial reefs, stock-enhancement programmes should be considered within the broader issue of fisheries management (Shams & Uwate, 1996). Stock enhancement is just one tool available to fisheries managers. In isolation, it will not cure an overfished fishery, or compensate for structural problems within a fishery.

In Bahrain, a major marine resource issues is illegal fishing (Directorate of Fisheries, 1993). Given the magnitude of illegal fishing activities, the benefits of even large-scale fish-release programmes may be compromised. Efforts continue to address this problem.

Finally, as large-scale fish releases continue and more information becomes available, it would be appropriate to assess the costs and benefits of the fish stock enhancement project in Bahrain.

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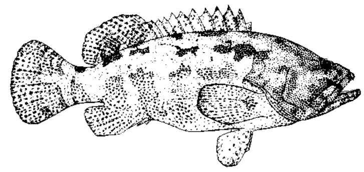

Grouper spawning aggregations need protection

by R.E. Johannes

Many coral reef food fishes aggregate in large numbers at specific locations, seasons and moon phases in order to spawn. Such fishes include groupers, the main objects of the live reef food fish trade.

These aggregations are prime targets for fishers, who often take large catches from them. Groupers have been virtually eliminated by overfishing in at least five Pacific Island locations within Palau, the Cook Islands, the Society Islands, the Tuamotus, and on the Great Barrier Reef. Fishing over spawning aggregations at three of these locations has been specifically implicated in their demise. It may also have been a factor in the other two cases.

One aggregation fished by Palauans for centuries was eliminated by a live reef fishing operation in just three years. It is very likely that a great many other aggregations of groupers have been eliminated without written record because the slowness with which Indo-Pacific marine biologists have recognised and acted upon the need to locate, characterise and protect them, even although descriptions of their importance and vulnerability have been in the scientific literature for almost 20 years.

Although details are hard to come by in many areas, it is clear that grouper spawning aggregations are under increasing pressure because of the live reef food fish trade and because of the ease today with which aggregation sites can be pinpointed and relocated with global positioning systems. In the Solomon Islands one Hong Kong company was even described by an ex-employee as using spotter planes and expert Chinese fishermen to locate likely grouper spawning sites using reef topography.

Accounts obtained from fishers in the Philippines and Indonesia reveal that they, also, are discovering increasing numbers of grouper spawning aggregations as the depletion of shallow-water resources forces them to dive deeper and further from shore.

One group of Indonesian fishers said they got such high catches from spawning aggregations they recently discovered that they no longer bother to fish for the trade during the non-spawning season. Such fisheries are not sustainable.

Marine resource managers should consider banning fishing on grouper spawning aggregations for a second reason. Gravid females are reportedly subject to significantly higher mortalities during shipment. (Most shipped groupers are females because they are the ones in the size range preferred by restaurants.)

The fish are treated with the anaesthetic MS222 prior to air shipment. This often causes gravid females to release eggs into the water of the shipping containers. The eggs clog their gills and probably also remove oxygen from the water. This appears to be one of the reasons for the higher mortalities, according to shippers, even among fish that are in prime condition.

Reducing transport mortality is in everyone's interests; every fish that dies means another must be caught to supply consumer demand for live fish. Some Australian live reef fish companies operating on the Great Barrier Reef have recognised that targeting of spawning aggregations is not in their own long-term best interests and actively support closing the fishery during spawning months.

The most widely discussed marine conservation measure in shallow tropical waters is the marine reserve. Proponents often assert that the most important function of marine reserves is to protect spawning stock biomass and ensure recruitment to fished areas by means of larval dispersal.

Clearly, for that reason, the boundaries of such reserves should, wherever practical, encompass spawning aggregation sites. There is little evidence in the literature, however, that spawning aggregation sites were given any consideration when the boundaries of most Indo-Pacific tropical marine reserves were drawn. Palau is a rare exception; the presence of an important spawning aggregation site is the main reason that the Palauan Government set up the Ngerumekaol marine reserve.

Spawning aggregations and associated sites are very poorly documented in the Indo-Pacific, except for certain Pacific Islands such as Palau. There is a great need for marine biologists in the region to locate reef fish spawning aggregations and to determine local spawning seasons (which vary from place to place within the region). There seems to be no scientific literature at all on grouper spawning aggregations in South-East Asia, although reports from South-East Asian fishermen indicate that they are well known to some.

This is an example of the fact that fishers often know far more about the location and timing of spawning aggregations than researchers. Indeed more than 20 different researchers have acknowledged in their publications that it was fishers who enabled them to locate the reef fish spawning aggregations that they subsequently studied. For this reason help from the latter should be sought when searching for and characterising these aggregations. Spawning seasons can often be determined simply by sampling at the market.

Live reef fisheries activities in the Republic of the Marshall Islands

by Dr Andrew J. Smith [1]

The following is based on information collected during a brief visit to Majuro, Republic of the Marshall Islands (RMI) in late June 1997, and subsequent communications with the Marshall Islands Marine Resources Authority (MIMRA) and RMI Environmental Protection Authority (RMIEPA).

Since late 1994 there have been three known live reef fish (LRF) operations in the Republic of the Marshall Islands. The first involved the arrest and prosecution of a LRF vessel operating illegally, and its subsequent re-arrest for possession of cyanide after obtaining a fishing licence. The other two are on-going joint-venture operations with local partners: one a Hong Kong-based company, the other based in Taiwan. From the perspective of the Director of the MIMRA, these two operations are still on a trial basis, and MIMRA is continuing to assess the fishery to ensure that maximum benefit accrues to RMI, with the minimum of negative effects.

Ocean Glory / Trekrona Ltd.: The M/V *Ocean Glory II* was arrested in early November 1994 near Ujelang (the westernmost atoll of RMI) by the RMI patrol boat for fishing without a licence. It was also suspected of fishing with cyanide, due to the way the vessel was set up, but none was found on board. The owner was fined US$ 250,000 and the vessel released after payment was made. The owner then applied for local government fishing permits (for Ujelang and Enewetak atolls) and a Foreign Fishing Agreement from the RMI Government in late 1995 and early 1996. Before it could start fishing, cyanide was found stored in plastic bags inside 55 gallon drums of oil, and the vessel was re-arrested in May 1996. The owner forfeited the vessel to the RMI Government. The vessel was built in 1968, has a steel hull, gross tonnage of 219.51 t, a length of 40.3 m, an engine capacity of 950 hp, fuel capacity of 110,000 l, a speed of 10.5 knots, and can carry a crew of up to 36.

Pacific Marine Resources Development Inc. (PMRD) is a locally incorporated company and was approved for a Foreign Fishing Agreement in November 1996 for an experimental live reef fish operation. It has a local government fishing permit for Maloelap, and is proposing to obtain a permit for fishing Ujelang in the near future. With this operation, PMRD charters a vessel from the Hong Kong partner, catches the fish, and transports it to Hong Kong for sale. To date two shipments have been made.

1. The Nature Conservancy, P.O. Box 1738, Koror, Palau

Marshall Islands Ocean Development, Inc. (MIOD) is a partnership between a Taiwanese company and local partners. It received approval for a Foreign Fishing Agreement in January 1997. The company was originally established as a tuna longlining operation to be based in Majuro, and installed fish handling and freezing equipment in a building adjacent to MIMRA. It was granted 10 longlining licences and was going to airfreight to Japan as well as loin the catch. For unknown reasons this did not eventuate and the company applied for an experimental live fish agreement. The current operation has been fishing Mili, Arno, Aur and Majuro. The company is chartering its vessel from the Taiwanese owners. This vessel, the *Lien Fu Tsai No. 2* (CT4-2131), is a fish carrier/longliner built in 1991 with a gross tonnage of 99.8 t, a length of 18.95 m, an engine capacity of 750 hp, a fuel capacity of 78,122 l, a speed of 11 knots, and a crew of up to 23. (*Note: On June 13, 1997, the FSS* Micronesia *(FSM patrol boat) arrested the* Lien Fu Tsai No. 2 *for illegally fishing in the Yap State Fishing Zone, while en route from Majuro to Taiwan for maintenance.*).

The live reef fishing operations in RMI are still in the experimental/trial stage, according to the MIMRA Director, and management and enforcement mechanisms are being developed as more experience is being gained in this form of fishery. The RMI Environmental Protection Authority is currently working with MIMRA and the International Marinelife Alliance–Philippines (IMA) to sample and test fish caught for traces of cyanide. IMA is a non-profit organisation based in Manila that has a contract with the Philippine government to test live reef fish for cyanide. It has offered to assist RMI in testing its samples.

Grouper aquaculture in Australia

by M. Rimmer [1], M. O'Sullivan [2], J. Gillespie [3], C. Young [4], A. Hinton [5] & J. Rhodes [6]

Abstract

Australia has an established wild capture fishery for grouper species in northern Australia. The major fishery is in Queensland, where the reef line fishery targets coral trout (*Plectropomus* spp.). The current commercial catch is estimated at about 1,200 t/yr with an additional 1,100 t caught by the recreational sector. In 1994, about 43 t of the commercial catch was exported as live product, most of which was air freighted to Hong Kong. Higher-valued species (barramundi cod (*Cromileptes altivelis*) and Maori wrasse (*Cheilinus undulatus*)), are uncommon.

Grouper aquaculture has only recently commenced in Australia, with two commercial hatcheries and one government hatchery commencing research on estuary cod (*Epinephelus coioides*) and barramundi cod. To date, no significant commercial production has been achieved. Because of the developing market for high-value live reef fish in South-East Asia, there is increasing interest in aquaculture of reef fish species, particularly groupers.

A feasibility study was carried out by the Queensland Department of Primary Industries (DPI) during 1995–96 to assess the potential to develop a reef fish aquaculture industry in Queensland to supply the high-priced live fish markets in Hong Kong and China. The overall plan for the feasibility study is shown in Figure 1 (see next page). A series of seven studies was carried out:

1. Present and future markets for selected live reef fish in Hong Kong and China;

2. Queensland's current reef line fishery and its potential to supply live fish, particularly coral trout;

3. Case studies of similar projects worldwide including time taken, development costs and difficulties;

1. Department of Primary Industries, Northern Fisheries Centre, P.O. Box 5396, Cairns, Queensland 4870, Australia.
2. Department of Primary Industries, G.P.O. Box 46, Brisbane, Queensland 4001, Australia.
3. Department of Primary Industries, Fisheries Group, G.P.O. Box 3129, Brisbane, Queensland 4001, Australia.
4. Department of Fisheries, P.O. Box 1625, Adelaide 5001, South Australia, Australia.
5. Department of Primary Industries, P.O. Box 1054, Mareeba, Queensland 4880, Australia.
6. 76 Bowen St., Cardwell, Queensland 4849, Australia.

4. Infrastructure required to service a live fish export industry;

5. Identification of sites suitable for land and sea cage-farming operations on the east coast of Queensland;

6. Detailed analysis of R&D requirements, and costing for a research programme to develop aquaculture techniques for high-value reef fish species;

7. Benefit / cost analysis of the R&D and subsequent commercial industry; and a financial evaluation to indicate the likely profitability of commercial farms that would commercialise the R&D output through live fish production and export sales.

Results of these studies are summarised in this paper. Because of the high cost of the proposed research, DPI is now assessing possible development of a joint government / private industry research project, as well as participation in collaborative research within the region. The Queensland Government has recently provided core funding to begin research into grouper aquaculture.

Introduction

Finfish aquaculture in tropical northern Australia is currently based almost entirely on production of barramundi (*Lates calcarifer*). Production of farmed barramundi has increased steadily since the late 1980s and 1995–96 production was about 460 t, valued at AU$ 4.9 million. Based on this success, the Australian tropical finfish aquaculture industry is keen to diversify by producing other finfish species, including snappers (Family Lutjanidae) and groupers (Family Serranidae).

Grouper aquaculture is currently only in the experimental stage in Australia. There are currently two commercial hatcheries that are undertaking research on the development of aquaculture techniques for estuary cod (*Epinephelus coioides*), one in Queensland and one in Western Australia. Commercial production of this species has not yet been achieved. Both these hatcheries are working in conjunction with Queensland Department of Primary Industries (DPI) aquaculture researchers. DPI researchers at Northern Fisheries Centre (NFC), Cairns, have previously undertaken research on common coral trout (*Plectropomus leopardus*) with reference to the development of aquaculture techniques for this species (Rimmer et al., 1994). More recently, we have commenced research on the development of aquaculture techniques for estuary cod and barramundi cod (*Cromileptes altivelis*) at NFC.

Queensland has recently seen the development of a fishery based on the capture and live export of reef fish species, principally the coral trout species (*Plectropomus* spp.). Because of the high wholesale prices paid for live reef fish in Hong Kong (see below), and concerns regarding the long-term sustainability of the capture fishery for live reef fish,

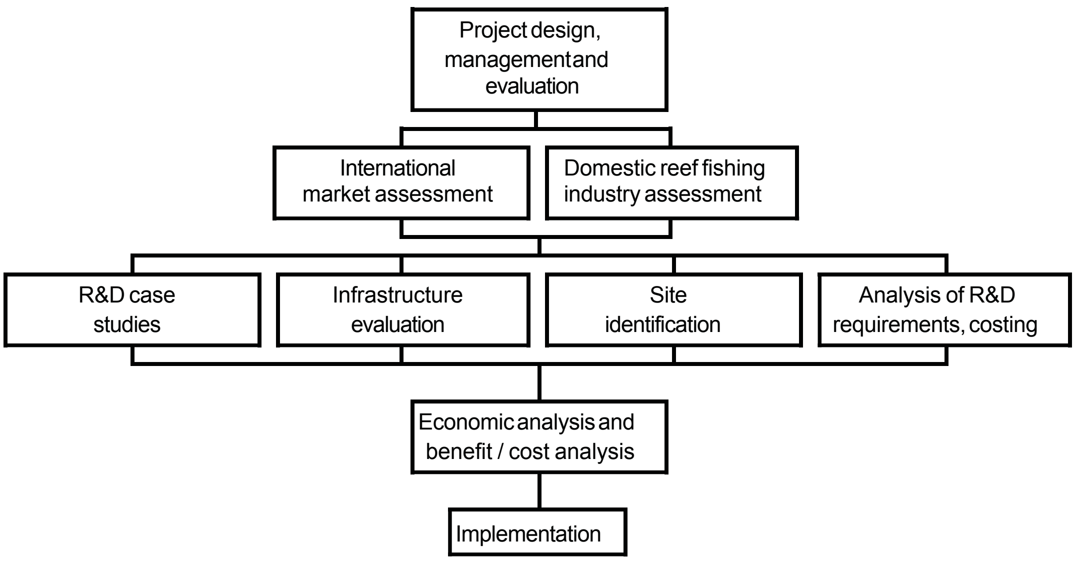

Figure 1

Network outline for studies carried out for the Reef Fish Aquaculture Feasibility Study

there is substantial interest in the development of an aquaculture industry for high-value reef fish destined for the live markets in Hong Kong and southern China.

In response to this interest, DPI undertook a feasibility study into the possible development of a reef fish aquaculture industry in Queensland. The overall objectives of the study were to determine what level of research and development (R&D) was likely to be required to develop a reef fish aquaculture industry, and whether the resulting industry was likely to be profitable enough to justify the costs of R&D to Queensland. Further details of this study are reported in the following section of this paper.

Reef Fish Aquaculture Feasibility Study

The Reef Fish Aquaculture Feasibility Study comprised seven individual studies which were undertaken by DPI staff, or by consultants in close collaboration with DPI staff. The overall study attempted to look at all aspects of R&D, production and marketing of high-value reef fish species specifically produced for sale in live markets in Hong Kong and southern China.

Market analysis

A market analysis was carried out by Hong-Kong based consultants, concentrating on the Hong Kong/southern China live marine finfish market. The total seafood market in Hong Kong is over 220,000 t/yr, and the current market for high-quality live reef fish is estimated to be 1,600–1,700 t/yr. Assuming that the Hong Kong and Chinese economies continue to expand at the current rate, both demand and price will expand in the immediate future. Compound growth rates in excess of 12 per cent are forecast, indicating that the market is expected to double every 6 years.

The demand for the highest-priced species, i.e. coral trout, barramundi cod and maori wrasse (*Cheilinus undulatus*), is currently only about 814 t. The average wholesale price (i.e. the price received by wholesalers from the restaurant trade) in 1995 for coral trout was AU$ 46/kg and for barramundi cod and maori wrasse was AU$ 87/kg.

Prices are forecast to be 60–100 per cent higher by the year 2003. The estimated wholesale market value for the top three species is projected to be AU$ 198 million in the year 2000, growing to AU$ 398 million by 2003. In addition to the market for live reef fish, there are substantial markets for whole, fresh-chilled product, although the extent of these markets was not investigated in this study. Existing supply sources are expected to be insufficient to satisfy projected demand. Wild stocks of finfish targeted for Asian live fish markets are reported to be severely depleted from overfishing and the use of unsustainable fishing practices, such as the use of cyanide (Johannes & Riepen, 1995).

Domestic reef fishing industry assessment

A desk-top study was undertaken to examine the capacity of the Queensland fishing industry for live reef fish to satisfy projected market requirements. This study used commercial catch records since 1989 and available research / management reports for the commercial sector of the reef line fishery to assess the capacity of this fishery sector to meet current and future market requirements.

The Queensland Reef Line Fishery is defined as all fishing that takes reef fish by handline, rod and line or troll line within the Great Barrier Reef Marine Park, which extends between the latitudes of 10° 41'S and 24°S on the continental shelf of north-eastern Australia. The fishery is divided into two main sectors: commercial and recreational. Fishing charter-boat operations are included in the recreational sector.

The combined annual commercial and recreational reef fish catch in this area is in the region of 8,000 t, of which coral trout and red throat emperor (*Lethrinus miniatus*) probably comprise as much as 2,300 and 1,000 t respectively (Brown et al., 1994). In the future, an increasing resource allocation problem is expected, due to the combined pressure of both recreational and commercial fishers, particularly near population centres.

The commercial sector of the reef line fishery is spread along the entire length of the reef system, with a concentration of catches and effort along the southern section of the reef, between Cardwell and Shoalwater Bay. Since it commenced in the 1930s there has been little change in the fishing methods used in this fishery. It is a hook-and-line fishery with recreational and commercial demersal reef fishers using very similar techniques and equipment. The fishery has a high level of latent effort. Although there are over 1,900 line-endorsed vessels, in 1994 50 per cent of the commercial coral trout catch was landed by only 30 commercial line-fishing vessels.

The demersal reef fish catch of commercial fishing vessels is about 1,600 to 2,400 t/yr (Table 1) and consists mainly of coral trout (59%). The value of this catch is estimated to be AU$ 6–10 million. Since 1989 commercial coral trout catches have varied between roughly 900 and 1,500 t/yr In 1994 1,100 t of coral trout were landed by commercial

Table 1: **Commercial catches (t) of coral trout (*Plectropomus* spp.), red throat emperor (*Lethrinus miniatus*), other demersal fish species, and total catch for the Queensland reef line fishery from 1989 to 1994**

Year	Coral trout	Red throat emperor	Other	Total catch
1989	930	419	298	1,646
1990	1,254	479	381	2,113
1991	1,427	516	387	2,329
1992	1,467	548	318	2,332
1993	1,260	538	240	2,038
1994	1,100	514	235	1,850

operators and an estimated 43 t of this catch were exported as live fish. There is significant spatial variation in coral trout catches, with the bulk of commercial catches of coral trout coming from the reefs south of Cardwell to Shoalwater Bay (latitudes 18°–22°S). Catches, effort and catch rates increase from a low in January each year to a high between September and November, which is the spawning period for coral trout. There have been industry suggestions that a fishery closure during the spawning season would assist in conserving coral trout stocks.

Although in the past virtually all captured coral trout were utilised in the domestic retail and restaurant markets, export of live reef fish is a rapidly growing component of the Queensland reef line fishery. According to Australian Quarantine Inspection Service records, 42.5 t of live fish were exported from north Queensland in 1994 and the Queensland Fisheries Management Authority reports that 47 t were exported in the first six months of 1995. Approximately 90 per cent of the fish exported are coral trout, 4 per cent are barramundi cod and a mixture of other reef species make up the remainder. Retaining live fish for export has been estimated to provide fishers with an increase in profit of around 30 per cent.

The stocks of coral trout on the Queensland east coast appear to be fully exploited due to the combined pressure of both recreational and commercial fishing. If the whole commercial reef line fishery converted from fillet product to live fish operations, it could potentially supply up 700 t of coral trout annually, which is a significant increase from the present 50–100 t. However, due to size and colour preferences, not all of this catch is suitable for the Hong Kong market.

There is considerable opposition to live reef fish exports from the recreational and fishing charter sectors of the community. This opposition is based on the perceptions that the live fish export industry is causing overfishing, is targeting small fish and is limiting supplies of reef fish that should be freely available for other fishers to catch and consume. Aquaculture of reef fish species could offer solutions to these problems by providing an adequate supply of suitable fish without affecting the reef fish wildstocks. This would help to protect the reef fish stocks from overfishing while allowing expansion of the live export industry.

Research and development case studies

The costs of R&D for established aquaculture industries were investigated for six different finfish species: Atlantic salmon, channel catfish, barramundi, European sea bass and European sea bream. The halibut industry was also included in the report as an example of an industry that has recently commenced commercial production following an extensive period of R&D, but that still has relatively low production. Costs were estimated for the 'set-up' phase of each industry, i.e. the time from commencement of research to the establishment of a viable commercial industry. Various experts from research and development institutions associated with each industry provided information on establishment costs and time for each industry investigated.

Costs of initial R&D for the establishment of commercially viable aquaculture industries were generally in the range AU$ 70–90 million, in cases where there was no or little existing technology base for these industries. In cases where there was an existing technology base, initial

Table 2: **R&D costs for finfish aquaculture industries, with duration of start-up R&D phase in brackets; and 1993/94 production quantity and industry value. N/A: denotes no information available and '–' not yet producing.**

Fishery	Country / region	R&D (AU$)	1993–94 industry production (t)	Value (AU$)
Atlantic salmon	Norway	90 million (8 yrs)	207,000	900.0 million
	Scotland	26.5 million (18 yrs)	65,000	520.0 million
	Canada	6.5 million (3 yrs)	13,500	132.0 million
	Australia	3.7 million (6 yrs)	4,000	48.0 million
Channel catfish	USA	70.2 million (15 yrs)	132,000	441.0 million
Barramundi	Australia	2.5 million (5 yrs)	350	4.0 million
European sea bass	Mediterranean	N/A	14,000	152.2 million
European sea bream	Mediterranean	N/A	14,000	139.6 million
Halibut	Norway	67.5 million (20 yrs)	100	1.6 million
	UK	3–5 million (15 yrs)	–	–

R&D costs were substantially less, generally in the range AU$ 2.5–26.5 million (Table 2).

The value of these industries is roughly proportional to the level of R&D funding provided for their establishment. For example, the Norwegian Atlantic salmon industry cost AU$ 90 million over 8 years and is now valued at AU$ 900 million p.a., and the channel catfish industry in the US cost about AU$ 70 million for initial R&D and is currently valued at about AU$ 441 million p.a. (Table 2).

Other factors that this study identified as being of importance in the development of viable aquaculture industries are:

- R&D funding is generally provided by government bodies, and by industry-based organisations. Initial funding is primarily provided by government, with industry picking up R&D costs as production commences and the industry becomes profitable;
- A wide range of R&D areas (e.g. water quality, production technology, fish health, engineering, environmental issues, breeding, and larviculture) needs to be incorporated in the R&D studies.

Infrastructure requirements

A study was undertaken to assess the requirements for infrastructure to support export of live reef fish produced by aquaculture. The study found that the infrastructure to handle holding, packaging and export of live fish is in place to support the existing export of wild-caught fish. Although air-freight may be limited during some periods of the year, overall the availability of air freight space is not expected to be a limiting factor in the development of a reef fish aquaculture industry.

Recently, the ban on imports of live seafood containers using oxygen into Hong Kong has decreased the profitability of live fish export operations, and has led to renewed interest in alternative packaging technology. It was suggested that fast sea freight will provide a more cost-effective method of transport of live fish to Asian markets.

Reef fish grow-out site identification and evaluation

A constraint on the development of a reef fish aquaculture industry in Queensland is the availability of suitable sites, and the impact that aquaculture would have on the natural environment. Most areas suitable for grow-out of reef fish would be in, or would potentially affect, the Great Barrier Reef Marine Park. This is a World Heritage listed area that is internationally renowned for its relatively undeveloped coral reef environment.

A desk-based study was undertaken by consultants to identify potentially suitable sites for grow-out of reef fish species on the eastern coast of Queensland. Areas zoned as having high conservation value were excluded from consideration.

The study identified areas suitable for cage culture and additional sites potentially suitable for land-based culture. Because of the limited nature of the study, it is likely that there are additional sites that are suitable for reef fish aquaculture that were not identified in the present study. This is particularly the case for land-based sites. Additional land based sites may be utilised if recirculating production systems are used to grow out reef fish species.

R&D requirements and costing

A major constraint to the development of a reef fish aquaculture industry in Queensland is the technical difficulty in rearing large numbers of reef fish fingerlings for grow-out. Currently, survival of reef fish larvae to fingerling stage is low (generally <5% and often <1%). A review of the scientific literature was undertaken to identify the main technical constraints in reef fish aquaculture.

Although a range of reef fish species is cultured in other parts of the world, in general the success of these operations is low and many culture operations rely on the capture of juvenile fish from the wild for grow-out operations. Such operations are not regarded as ecologically sustainable and are discouraged in Australia for this reason.

In Australia today, a viable aquaculture industry must be able to:

- produce marketable product cost-effectively, by rearing animals through to harvest size from captive broodstock, and
- do so while maintaining minimal or negligible environmental impacts.

The following discussion of research and development (R&D) requirements for a reef fish aquaculture industry is based on these two important factors.

Queensland has a useful model for the development of a finfish aquaculture industry in the barramundi industry. The development of this industry has been supported by research carried out by the DPI. The progress of barramundi aquaculture in Queensland has shown that the development of a viable, relatively large-scale industry is dependent on:

- a reliable supply of high-quality larvae from captive broodstock;
- cost-effective larval rearing techniques;
- nursery and grow-out techniques that maximise survival and minimise production costs;
- existing markets for aquaculture product, and a marketing strategy for increasing production.

DPI's extensive experience in developing techniques that are now in use by the barramundi aquaculture industry has been used in determining the R&D needs for the development of a reef fish aquaculture industry.

Species selection

The discussion of R&D requirements focuses on coral trout and barramundi cod as the species of principal interest for reef fish aquaculture. However, a wider scan of species suitable for reef fish aquaculture was undertaken in order to avoid limiting species consideration at this early stage.

Several *Epinephelus* species were considered because there is an abundant literature on this genus, and because much of the information regarding *Epinephelus* culture is directly relevant to the closely related coral trout and barramundi cod. In addition, there is a significant body of opinion that *Epinephelus* species could support an aquaculture industry component in their own right. Assuming that technological advances allow routine and inexpensive larviculture, the farm gate production costs could be similar to those currently achieved on Australian barramundi farms.

Species considered in this study were:

Coral trout	
Plectropomus leopardus	Common coral trout
Plectropomus laevis	Blue-spot trout
Plectropomus maculatus	Barred-cheek coral trout
Plectropomus areolatus	Passionfruit coral trout
Cod	
Epinephelus coioides	Estuary cod
Epinephelus tauvina	Gold-spot cod
Epinephelus malabaricus	Black-spot cod
Epinephelus fuscoguttatus	Flowery cod
Barramundi cod	
Cromileptes altivelis	
Wrasse	
Cheilinus undulatus	Humphead Maori wrasse

Critical aspects of R&D, identified by this study, were:

- maintenance of captive broodstock and development of captive breeding procedures;
- identification of live prey organisms suitable for use in larval rearing;

Table 3: Proposed R&D programme for the development of reef fish aquaculture in Queensland

	Duration	Main aims
Phase 1	4 years	Establish captive broodstock of at least 3 species. Develop spawning techniques for these 3 species. Undertake initial feeding and larval rearing trials. Develop culture techniques for copepods and other zooplankton prey.
Phase 2	3 years	Develop 'on demand' spawning techniques for the 3 fish species used in Phase 1. Commence development of spawning techniques for at least 1 additional species. Refine zooplankton production techniques. Develop reliable larval rearing techniques.
Phase 3	3 years	Refine spawning and larval rearing techniques. If possible, expand to other species. Undertake grow-out trials in conjunction with industry.

Table 4: Summary of indicative funding for an R&D programme to develop reef fish aquaculture in Queensland

Component	Phase 1 Years 1–4	Phase 2 Years 5–7	Phase 3 Years 8–10
Broodstock	965,000	642,000	497,000
Larviculture	973,000	728,000	725,000
Live food	1,868,000	1,318,000	1,240,000
Grow-out	1,450,000	921,000	980,000
Administration	984,000	421,000	417,000
Total (AU$)	**6,240,000**	**4,030,000**	**3,859,000**

- development of culture techniques for selected live prey organisms;
- development of larval rearing techniques;
- development of culture systems that provide for minimal environmental impact in the Great Barrier Reef Marine Park and adjacent waters.

Central to the R&D requirements for reef-fish aquaculture is the provision of high-quality reef water. A number of possible sites for the R&D programme are briefly discussed in the report, based on their access to water of suitable quality and their proximity to existing research facilities.

The R&D programme has been planned for a period of 10 years, split into 3 phases of 4, 3 and 3 years duration respectively (Table 3).

Continued funding of the later phases of the project would be contingent on achieving the milestones established for the previous phase. The indicative funding for the proposal totals around AU$ 14 million (Table 4).

The proposed R&D programme was designed to reduce the risk of not achieving the desired outcomes by investigating several reef fish species simultaneously, and selecting those that had the greatest potential for aquaculture.

However, it should be emphasised that even incorporating this strategy, and with the costly R&D programme outlined above, the development of reef fish aquaculture techniques should be considered a high-risk project.

An alternative strategy to the full R&D proposal costed in the report is the establishment of a smaller research effort, carried out in conjunction with overseas research organisations, mainly in South-East Asia. This has the following advantages:

- utilisation of existing expertise from these countries;
- lower R&D costs to any one participating country;
- reduced overall risk due to wider participation in R&D activities.

However, adoption of this option may reduce Queensland's competitive advantage in producing fish for live fish markets in the future.

Benefit/cost analysis and financial evaluation

A benefit/cost analysis was performed to indicate whether the substantial expenditure required to develop a reef fish aquaculture industry would result in positive economic returns for Queensland.

The benefit/cost analysis model used was based on the Grains Research and Development Corporation procedure (GRDC 1992) and required an estimate of the success of the R&D programme for each species.

Although it is difficult to predict the eventual success of culture of reef fish species, particularly in view of the paucity of biological information on most species and the high variability of survival found by other aquaculture researchers, the following probabilities were used for the benefit/cost analysis:

- coral trout: 20.0 per cent,
- Maori wrasse: 7.5 per cent,
- barramundi cod: 15.0 per cent.

It is considered that these figure are conservative, and that more accurate estimates of the probability of success can only be achieved following further research into aquaculture techniques for these species.

Other assumptions used in these models were:

- the R&D programme outlined above is successful, particularly with the extremely high-valued species such as barramundi cod;
- high market prices are maintained, as indicated in the marketing study, although prices were assumed not to increase past year 2000 forecasts because of increased supply from aquaculture;
- market demand continues to grow due to population increase and increasing affluence in China and Hong Kong;
- industry adoption commences in the tenth year of research and builds up to an industry with a production level of 2,500 t after 10 years and 7,000 t after 20 years;
- fish reach a preferred market weight of 1 kg after a grow-out period of 24 months.

Epinephelus species were not considered in the benefit/cost study or the financial evaluation. The relatively low value of these species (compared with coral trout, Maori wrasse, and barramundi cod) does not justify the high level of research expenditure indicated by the 'R&D Requirements and Costing' study.

The benefit/cost model showed that a reef fish aquaculture industry in Queensland has the potential to be highly profitable, generating revenue in excess of AU$ 1 billion within 30 years under favourable conditions.

Using an 8 per cent discount rate over 40 years, the net present value of the research project could be of the order of AU$ 170 million, with a benefit:cost ratio of 16.6:1.

The financial evaluation (based on the economics of 100 t/yr production units, both land-based and offshore cages) indicated that farming reef fish species is potentially highly profitable.

Internal rates of return in excess of 100 per cent were indicated for aquaculture of barramundi cod and Maori wrasse, and 50 per cent for coral trout. Labour, feed and fingerling costs constitute the critical production costs. Harvesting, marketing and transport account for approximately 50 per cent of the overall costs, but might be reduced through changes in transport technology and increased economies of scale for larger production units.

Conclusion

With an increasing population base and growing affluence in Hong Kong and southern China, the market for live seafood, including live reef fish, seems set to increase for the foreseeable future. Prices are forecast to increase steadily for at least the next six years. It appears unlikely that this demand can be fully met by capture fisheries, particularly in view of the widespread environmental damage caused by unsustainable fishing techniques such as the use of cyanide and dynamite in many fisheries (Johannes & Riepen, 1995). Even where such practices are not used (e.g. the Queensland reef line fishery), there is relatively little potential for expansion of the capture industry. Increasing demand for live reef fish will have to be met by aquaculture product.

Our studies have shown that R&D costs for the development of a reef fish aquaculture industry are high, although comparable with the R&D costs for establishment of other finfish aquaculture industries. However, returns are also likely to be high, and the established industry should be highly profitable.

The main constraint to the development of a viable reef fish aquaculture industry is the technical difficulty associated with producing large numbers of fingerlings for grow-out. Although this aspect is specifically targeted in the proposed R&D programme, it is generally recognised that investment in R&D for reef fish aquaculture is high-risk, albeit with potentially high rewards.

The Queensland Government has recently encouraged the development of a reef fish aquaculture industry by supporting core research into the development of aquaculture techniques for high-value reef fish species at NFC. However, the level of funding supplied is well below that estimated in the Reef Fish Aquaculture Feasibility Study as being required to develop a viable industry within 10 years.

Consequently, additional funding will be required to facilitate industry development. While private investment funding is still being sought to facilitate commencement of the full R&D programme outlined above, there is also strong support for a coordinated regional approach to R&D for reef fish aquaculture.

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Additional information

A summary of the Reef Fish Aquaculture Feasibility Study findings (Industry Potential Snapshot brochure) is available from the authors of this paper, or from DPI Publications (see below).

Copies of individual reports from the Reef Fish Aquaculture Feasibility Study are available from:

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Research, not rumours, needed for live fishing industry

by Annabel Miles [1]

Recent debate on Queensland's expanding live reef fish trade has prompted fisheries scientists to study this new industry and provide much needed information to fisheries management agencies. Much of the public criticism relates to a perception that the live fish trade will rapidly deplete targeted local fish stocks through overfishing—concern which apparently stems from publicity about destructive fishing practices in other countries. So what are the facts about live fishing on the Great Barrier Reef? How does it affect the resource and how does this industry work?

The CRC (Co-operative Research Centre Program) Reef Research Centre's Effects of Line Fishing team is currently researching this new industry, to replace the dogma with facts, and address some of the public concerns. The research, funded by the Fisheries Research and Development Corporation and the CRC Reef Research Centre, will provide accurate information about the activities of fishers and impacts of the live fish industry.

Project leader Dr Bruce Mapstone says: 'Little data currently exists on fishing for the live export trade. We don't know how much live fishing differs from traditional commercial fishing, and if it does, how this will impact on the reef. We do know that basic fishing activities have not changed. For example, fish are still caught on the Great Barrier Reef by hook-and-line, and none of the very destructive practices used elsewhere are being used here,' Dr Mapstone said.

'In some aspects of the live fish industry changes are evident, such as the need for shorter fishing trips. It is important to verify, however, whether current management strategies, based on traditional practices, are appropriate for a fishery dominated by the live fish trade,' he said. 'That is why agencies such as the Queensland Fisheries Management Authority and the fishing industry believe there is an urgent need for scientific research into the live fish industry to ensure its proper management'.

Bruce Mapstone, with CRC colleagues Campbell Davies, Kev Kane and several other fisheries researchers, has already spent considerable time on the docks talking to fishers. This time has been well spent, resulting in useful information which has increased understanding of this new industry.

'Since 1993 when the first coral trout was exported live, the trade grew to more than 20 per cent of all sales in 1995 from some regions of the Great Barrier Reef,' Bruce reported.

According to accounts from fishers, there have been further increases in the trade since then, especially in the Cooktown-Bowen regions. Several facts which set live fishing apart from more traditional fishing techniques are already coming to light.

Keeping fish alive for export requires careful handling and holding to reduce stress, which may lead to increased susceptibility to disease and infections. This may result in increased handling time for each fish and reduction in holding capacity on the main boats. The overall affect of this may be decreased effective fishing effort. More careful handling by fishers in dories may also mean a reduction in catch rates.

'Such a reduction in catch rates could be interpreted by management agencies as a sign of declining fish stocks, whereas in this case it may actually arise from changes in fishing practices,' Bruce explained.

Currently, fish can only be kept in holding facilities on board primary boats for around five to seven days before the risk of disease, stress and other holding problems become critical. Also fish do not react well to transport over long distances when stored on board, especially in rough conditions. It has been suggested that these factors may result in skippers being less likely to fish on more distant reefs when fishing live.

This may lead to a concentration of commercial fishing effort nearer to ports—regions also

1. CRC Reef Research Centre, James Cook University, Townsville, Australia

favoured by recreational fishers and charter boat operations.

The results of this may be an increase in fishing effort on reefs adjacent to major coastal towns, but no net increase over the whole Great Barrier Reef. As yet there is no clear evidence to support or counter such speculations.

Plate-size coral trout (38–45 cm) are favoured for the live fish industry and it has been suggested that fishers are 'targeting' smaller fish than they may have in the past, while still observing minimum size regulations. Live fishing may then have different impacts from traditional fishing on size, age and consequently sex distribution of the coral trout population (since coral trout change sex as they get older). 'This sort of information is an important consideration for future management strategies,' Bruce stated.

This first couple of years of live fishing saw a large number of boats convert from traditional fishing to fishing live, rather than new fishers entering the industry. In general there was probably no net increase in fishing effort. However, with increased interest in the industry, the future could see new fishers buying fishing endorsements that have previously been dormant. Recent data from the Queensland Fisheries Management Authority suggest that this might now be happening. The result of this could be increased fishing effort in the future. This possibility should be investigated carefully, and considered by management agencies.

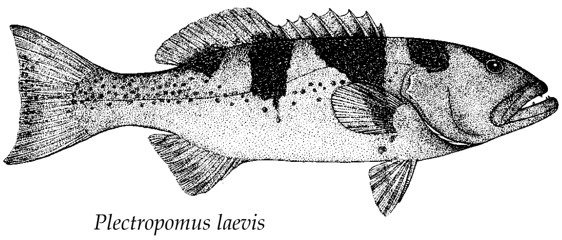
The first step of this research is to compare catch rates (the number of fish caught per unit of fishing effort) in the live fish industry with that fishing for dead product. 'If catch rates differ between live fishing and traditional fishing, managers will have to take this into account when interpreting information from the fishery', Bruce said.

Secondly, the behaviour of the live fishing fleet will be examined and compared with the fleet that lands fish dead. Questions here include: how many boats are involved in the live fishing industry, where do they go and how long are their trips? These patterns will provide information on what areas in the Great Barrier Reef are favoured by those selling live fish, and whether the focus of commercial fishing has changed with the development of the live fish trade.

The analysed results from this research will improve public understanding of the live fish trade and dispel some of the myths surrounding the industry, as well as providing information to improve its management. The public will be kept up-to-date with all results as they become available. Fishers will also have access to all published reports to assist in the management process of this new fishery.

'Accurate information from the research is crucial to successful management. The information will be made widely available throughout the duration of the project in a number of formats including articles in popular fishing magazines and papers, features in the CRC Reef Research Centre's Effects of Line Fishing newsletters, updates in the media and on the Internet, and in published Technical Reports,' Bruce said. A comprehensive final report will be available on completion of the project in 1998.

Source: *The Queensland Fisherman*, July 1997



Plectropomus laevis

Policy reform and community-based programmes to combat cyanide fishing in Philippines[1]

by Charles V. Barber[2] & Vaughan R. Pratt[3]

Prepared for the expert consultation on: *Closing the loop: Natural resource-management oriented agricultural research and policy change*. European Centre for Development Policy Management, Maastricht, The Netherlands, 10–11 November 1997

1. Cyanide fishing: A poison tide on the reef

Since the 1960s, more than a million kg of deadly sodium cyanide have been squirted onto coral reefs in the Philippines to stun and capture ornamental aquarium fish destined for the pet shops and aquariums of Europe and North America. More recently a growing demand for larger reef food fish has vastly increased the incidence and spread of cyanide fishing. Chinese consumers in Hong Kong and other major Asian cities greatly value certain reef fish when they are plucked live from a tank, cooked, and served minutes later, and pay up to US$ 300 per plate for some species. The combined demand for aquarium and live food fish has spread cyanide fishing throughout Indonesia and into neighbouring countries such as Papua New Guinea, Vietnam, the Maldives and Fiji. In the past year, officials in countries as far-flung as Eritrea, the Marshall Islands, and Tanzania have voiced suspicions that their fast-growing live-fish export industries may also be using cyanide.

Far from Hong Kong's restaurants and the pet stores of Europe and North America, fishermen in South-East Asia, the Indian Ocean, and the Pacific dive into the sea with 'hookah' tubes in their mouths—attached to air compressors on small boats—and makeshift squirt-bottles in their hands. These fishermen squirt cyanide into coral formations, thereby stunning and collecting their prey. Sometimes a crowbar is necessary to pry apart the coral heads and reach the stunned fish that hide in crevices. The rewards are high, with some cyanide divers making more money than the university professors in their countries, but so are the risks. Untrained in diving safety, many fishermen fall prey to decompression sickness ('the bends') Contributing to this chain of poison are a variety of intermediaries—vessel and holding-tank facility owners, fish exporters and importers—and civilian, police, and military officials who look the other way for a cut of the profits.

Cyanide kills corals and reef invertebrates along with many non-target fish. Large percentages of the fish that are captured live die in transit, due to their poison-weakened state. Deadly in any marine environment, the spread of cyanide fishing is particularly tragic in the countries of the Indo-Pacific. As the global centre of marine biodiversity for corals, fish, molluscs, and reef invertebrates, the region may justifiably be called 'the Amazon of the Oceans'. cyanide fishing also threatens the livelihood of poor coastal people in the region, where dependence on fish protein is very high and fisheries provide millions with income.

The Philippines, birthplace of cyanide fishing, is also the only country with a programme in place to eradicate the practice. Since the early 1990s, the Bureau of Fisheries and Aquatic Resources and the International Marinelife Alliance–Philippines (IMA), an NGO, have jointly developed and implemented the Cyanide Fishing Reform Program (CFRP). Experience with the CFRP over the past five shows that cyanide fishing can be reduced through a combination of the right policies and laws, beefed-up enforcement efforts, enhanced public awareness, cyanide testing of live-fish

1. This paper summarises data and conclusions found in *Sullied Seas: Strategies for combating cyanide-fishing in Southeast Asia and beyond* by Charles V. Barber and Vaughan R. Pratt, published by World Resources Institute and International Marinelife Alliance–Philippines, September 1997.
2. Senior Associate, World Resources Institute
3. President, International Marinelife Alliance–Philippines

exports, training of cyanide fishermen in cyanide-free live-fish capture techniques, and development of sustainable community-based resource management and livelihood alternatives that transform local fishermen into the front line of marine stewards and protectors.

One key aspect of the CFRP's initial success has been initiation of policy reforms in both source and consumer countries to create anti-cyanide fishing incentives and enforcement mechanisms. A second important element has been development of effective partnerships with fishing communities themselves, focusing on transfer of non-destructive technology and improvement of local livelihoods.

This paper identifies the key actors in the live-fish trade and analyses their roles and interests, elaborates the policy reforms governments of both exporting and importing countries must take to establish incentives for a cyanide-free live-fish trade, and examines the community-based strategies that lie at the heart of the CFRP's efforts to counter this ominous threat to the very heart of the planet's marine biodiversity.

2. Actors in the live reef-fish trade

The live reef-fish trade in South-East Asia has an estimated annual retail value of at least US$ 1.2 billion, about US$ 1 billion from the live food-fish trade (mostly with Hong Kong), and nearly US$ 200 million from exports of aquarium fish to Europe and North America. Not all of the fish in the trade are caught with cyanide (Australia's live reef fishery, for example, is cyanide-free), but most of them are. To understand the dynamics of this trade, it is necessary to understand the various actors involved and the incentives that currently shape their behaviour.

Cyanide fishermen

The number of cyanide fishermen operating in Southeast Asia and neighbouring countries is unknown. Based on estimates in the Philippines, where there are probably about 4000, the number of hard-core cyanide fishermen throughout the Indo-Pacific region probably does not exceed 20,000. In short, cyanide fishing is not a ubiquitous problem like slash-and-burn farming, practised by millions of poor farmers. Nor is poverty the root cause of cyanide fishing, although many cyanide-fishermen are certainly very poor. Rather, cyanide fishermen are a fairly small and discrete group who are responding to very specific incentives: a new technology, a ready market for the product, lax government enforcement of anti-cyanide laws, and the lack of viable livelihood alternatives.

Experience in the Philippines suggests that when cyanide fishermen are introduced to cyanide-free techniques for live-fish capture and ensured a fair price for their catch, they are willing and often eager to give up using the poison and to talk about ways to ensure the long-term sustainability of their local reefs and fisheries. Development of reliable alternative sources of income strengthens these incentives, and strict government enforcement of anti-cyanide-fishing laws further reinforces them.

Live reef-fish exporters

The number of companies involved in the live-fish export business in South-East Asia is also unknown, but it appears to be expanding rapidly. In the early 1960s, for example, there were only three companies exporting aquarium fish from the Philippines and export of live food fish did not yet exist. By the 1990s there were some 45 aquarium fish exporters in the country, and eight companies exporting live food fish. At least 10 companies run holding tanks for live food fish in Bali, Indonesia, a major transshipment point. Conservative estimates of the annual volume of Asian trade in live food fish alone range between 20,000 and 25,000 t, mostly from Indonesia, and the real total may be far greater. Philippine government statistics show that as many as 6 million aquarium fish were exported in 1996, and Indonesia is catching up quickly.

Exporters of cyanide-caught live food and aquarium fish are responding to a strong market demand and the lack of meaningful law enforcement and monitoring by governments. Partnerships with the exporters for more sustainable live fisheries are only possible when source-country governments take strong action to eradicate the export of cyanide-caught fish and importing countries demand proof that incoming fish were not caught with cyanide.

Live reef-fish importers

Businesses that import live food and aquarium fish are in essentially the same position as exporters: in the absence of government pressure to ensure that the fish they import were not caught with cyanide, they have little incentive to take action on the issue. As one large importer of live food fish argued: 'We the Hong Kong importers do not participate in any catching of fish or its activities. We just finance the people by equipping them with boats and fishing gear. We just buy fish from them. The production side is left to them.'

Live reef-fish consumers

Consumers have an important role to play in pressuring the aquarium-fish industry to take action on imports of cyanide-caught fish. Indeed, publicity and ensuing consumer pressure in Europe and North America has had some impact on aquarium-fish importers, and led to efforts such as the Marine Aquarium Fish Council in the US, discussed below. Consumer pressure against cyanide fishing is virtually non-existent among the Chinese consumers of live food fish, though. As one Hong Kong observer noted, 'being endangered actually seems to spur demand.'

Divers and dive operators

Scuba diving and snorkelling on tropical reefs are a big and growing business throughout the Indo-Pacific. Divers and dive operators have a strong interest in maintenance of coral reefs and healthy fish populations, and are often vocal in their support for marine conservation. Effective mechanisms have not yet been developed, however, to fully tap this group for political and financial support in combating cyanide fishing, although some efforts such as PADI's Project Aware are working to instill greater general environmental consciousness in divers and dive operators.

Engaging these diverse people in efforts to combat cyanide fishing requires two basic elements. First, government policies must provide a structure of negative and positive incentives which make cyanide fishing unattractive for the whole range of actors involved in the trade and make sustainable alternatives attractive. Second, partnerships must be developed directly with fishing communities currently using cyanide, to assist them in abandoning the cyanide-fishing tradition and adopting techniques, technologies and economic strategies which improve their livelihoods while protecting their rich marine environment.

3. Policy reforms to combat cyanide fishing

Cyanide fishing will not end until governments set in place effective policies to eradicate it and to encourage sustainable live-reef fisheries. The use of cyanide to catch fish is illegal in virtually every country of the Indo-Pacific, but the big profits to be made, combined with lack of enforcement and other supporting actions mean that with the exception of the Philippines, these laws do not much discourage cyanide fishing. 'Policy reform' in this context, therefore means more than passing laws. It also involves establishment of effective institutions to monitor the live reef-fish trade, enforce the laws, and provide economic incentives for fishermen, traders and consumers to shift to ecologically sustainable, cyanide-free reef fisheries.

Policy reforms in live reef-fish source countries

Establish cyanide detection test (CDT) laboratory facilities at all major live-fish collection and transshipment points

A simple test to determine the presence of cyanide in live fish was developed by IMA and the Bureau of Fisheries and Aquatic Resources (BFAR) and has been in use for over five years in the Philippines. Currently five laboratories test over 6,000 samples annually. An effective CDT testing network is the key for a strong effort to reduce cyanide fishing. Without testing, authorities cannot determine whether fish have been caught with cyanide or obtain convincing evidence to prosecute violators.

To be successful, CDT labs must also be backed up by a larger network of agencies and monitoring posts, and staff trained in sampling prospective live fish shipments and rapid sample transport. Such a network requires directives on participating in sampling and monitoring from central agencies to their local offices, and training in correct sampling and shipping-to-lab procedures.

Although testing is not a panacea, it is the best technical tool currently available to identify cyanide-tainted fish and provide hard evidence with which to prosecute violators. Countries that want to provide incentives to stop cyanide fishing must be serious about developing their capacities to systematically test live fish intended for export.

Establish a national system of data gathering and monitoring that provides useful data for regulating the live-fish trade

In order to monitor and regulate the live-fish trade, governments need accurate and appropriate data. Many national systems for collecting fisheries and export statistics do not adequately disaggregate data, making it impossible to tell, for example, how many individuals of a particular species were collected in a particular location, exported in a given month or year, or who did the collecting and exporting. There is no way to regulate cyanide use in the live-fish trade until such data are regularly collected.

The Philippines now collects live-fish data in ways that allow the government to keep a watch over total numbers of particular fish species moving through domestic and international airports and major international seaports, activities of exporters, and other relevant information. IMA collects the data through its CDT and monitoring network, and provides it to all relevant national and provincial government offices.

Establish a firmer legal framework to detect and prosecute cyanide fishing and trade in cyanide-caught fish, ultimately requiring mandatory testing and certification of all live reef-fish exports

While fishing with cyanide and other poisons is banned in virtually every country in South-East Asia and the Pacific, a much firmer legal framework in needed to make these bans effective. Once a CDT laboratory and monitoring network is established, all prospective exporters should be required to submit to random sampling and testing, inspection, and government licensing. All shipments should require a certificate showing the origin, volume, and species composition of the shipment, and certifying that it has been subject to random CDT procedures and is cyanide-free.

A mandatory certification system (as will be established by law in the Philippines in late 1997) provides key positive as well as negative incentives for exporters. On the one hand, uncertifiable fish become liabilities. On the other hand, certified fish can obtain an 'environmental market premium' in markets where importing governments regulate imports and consumers prefer fish caught without cyanide.

Enforcement procedures and penalties must be fairly applied, and should focus on punishing the larger players in the trade, such as exporters and corrupt officials, and not unduly persecute the cyanide divers themselves. Governments might consider enacting strong forfeiture provisions to prosecute large operators. With this approach, violators would lose not only fish which test positive for cyanide, but also equipment such as boats and holding facilities proven to have been used for cyanide fishing.

Nonetheless, local cyanide divers should be educated to realise that what they are doing, for whatever reasons, is illegal, and that repeat offenders will be punished harshly. This will only be perceived as just, however, when local fishermen see the big operators prosecuted first. Targeting the big cyanide fishing interests also reduces incentives for local divers to join in the trade.

*Ban or restrict the export of especially vulnerable species, such as the Napoleon wrasse (***Cheilinus undulatus***)*

Blanket bans on the live reef-fish trade are both unwise and unworkable[4] and just drive the trade underground. When the Philippines attempted a ban in parts of Palawan Province several years ago, cyanide fishermen continued to use the poison, but killed the fish after capture and sold them on the fresh-fish market. Also, bans deprive local communities of one of the most lucrative sources of income to be found in the coastal zone. The cyanide-free capture of live fish at sustainable levels with a fair return to local fishermen should be the objective of live fishery policy.

That said, the pressures on particular species may become so great that governments may want to ban their capture and export altogether. For the napoleon wrasse, highest-valued of the live food-fish species, over-exploitation may soon reach critical levels, warranting a complete ban. A ban is unlikely to stop the napoleon wrasse trade altogether, but it may reduce the total volume.

Regulate the import, distribution and use of cyanide

Cyanide has many legitimate uses in industry but a considerable amount of the poison is diverted into the live-fish collection business. In most countries of the Indo-Pacific region, import, distribution and use of cyanide is virtually unregulated. To remedy this problem, a draft 'Sodium Cyanide Act' that would strictly regulate the import and use of cyanide was introduced in the Philippine House of Representatives in late 1996. The draft bill requires all cyanide imports to be authorised in advance by the government, and requires the poison's sale to be 'strictly controlled'. Control elements include requirements for traders and end-users to seek authorisation from the Department of Envi-

4. Editor's note: It is true that a total ban is unworkable in large, spread out countries such as the Philippines and Indonesia. It is practical, however, in some small, compact Pacific Island countries.

ronment and Natural Resources (DENR) to purchase, distribute or use cyanide, and to file weekly reports on the sale or use of the substance. Both traders and buyers would be subject to spot checks by the government. Penalties under the Act are stiff, with prison terms for unauthorised possession or importation of cyanide ranging from 6 to 12 years and fines set at a minimum of US$ 10,000.

While this type of law will undoubtedly be difficult to enforce, it should nonetheless increase the price of cyanide on the black market, thus making non-destructive techniques of live-fish capture more economically attractive to fishermen currently using cyanide.

Address corruption within vulnerable government units such as fisheries, the navy, customs, and police forces

The ease with which government officials charged with regulating the live fish trade can be bribed in many places works against all of the other incentives that source-country governments might put in place to stop cyanide fishing. But with so much money at stake in the cyanide-based live fish trade, corruption is a recurrent problem.

Governments can only eliminate corruption if officials at the highest levels take firm public stands against it, and when corrupt officials are dealt with harshly under the law. Heads of vulnerable agencies such as fisheries, the navy, and customs must establish firm policies that those convicted of involvement in cyanide fishing will be summarily fired and permanently barred from civil service or military positions. National police agencies and prosecutors can make it known publicly that they will seek the maximum penalties available under the law to prosecute corrupt officials.

The media can help by exposing instances of corruption related to cyanide fishing in the press. Even in societies where the press is restricted, firm government policy statements against cyanide fishing and related corruption should give the press a freer hand in reporting abuses. Finally, an effective CDT lab and monitoring network, backed up by community-based monitoring, can provide government with a great deal of information about potential corruption problems.

Mount public awareness campaigns in the media and schools

NGOs and government leaders should work systematically to build public awareness about the threat of cyanide fishing and the steps that must be taken to stop it. Press releases, symbolic public events, and the steady provision of information to journalists are all tools that can raise public awareness and strengthen other anti-cyanide-fishing incentive measures.

In the schools, information on the values of marine resources and biodiversity, the effects of cyanide-fishing, and the tools available to stop it should be integrated into curricula from primary school onward. Cyanide fishing is a learned behaviour that becomes a tradition over time. By teaching the cyanide-free tradition in coastal-area schools from an early age, countries can help to ensure that children are fully aware of the alternatives to cyanide fishing and their positive consequences.

Divers are also potential allies in raising awareness and gathering information. In the Philippines in 1994, IMA initiated a voluntary Status of Coral Reefs (SCORE) survey, using a simple questionnaire on reef conditions which divers were asked to complete and return by mail.

By mid-1996, 200 of the 4,000 survey forms distributed by IMA had been completed and returned, providing the first new primary data on the condition of Philippine coral reefs since a survey done in 1983, including reports on suspected cyanide-fishing locations.

Policy reforms in live reef-fish importing countries

As in any transnational trade, source countries for live reef fish need the cooperation of importing country governments if their efforts to stem cyanide use at home are to be effective.

At present, no importing country requires proof that imported live fish were not caught using cyanide, or penalises firms that import fish caught with the poison. Key steps for setting up more helpful incentives in importing countries include the following:

Monitor imports of live fish and provide data to exporting countries

Importing country governments should establish data collection and storage systems to keep track of the number by species of live fish imported, and the country of origin. They should then share those data with relevant government agencies in source countries. In this way, monitoring agencies in source countries can compare their own export statistics with import statistics and thus determine the validity of those export statistics—provided exporting countries begin to collect detailed export data, as the Philippines is already doing.

Establishing partnerships with live-fish exporters and importers

Along with establishing partnerships with fishing communities, effective policies to combat cyanide fishing must also cultivate support from other private sector actors in both source and importing countries. Some of the most important steps in this regard include the following:

- **Ensure that testing of fish for cyanide is done rapidly, fairly and efficiently**

  As already noted, establishment of cyanide-detection testing (CDT) capacities and requirements is an essential incentive for discouraging cyanide fishing. But speed is essential if cyanide-testing is to gain the support of legitimate exporters, who do not want their business unduly delayed by red tape. To that end, laboratories need to follow the Philippines' model and function seven days a week, returning test results to the exporter (with a cyanide-free certificate if the tests are negative) within 24–36 hours. Equally important, the agency managing CDT labs must be trusted to be fair, efficient, and incorruptible by the fish collectors and exporters.

- **Provide and publicise official cyanide-free certification**

  As demand for cyanide-free live fish grows in overseas markets, fish that exporters can claim as reliably cyanide-free can command a higher price. This was proven in the 1980s when aquarium fish from the Philippines, tainted with that country's cyanide-fishing reputation, began to command a lower price than the same species from Indonesia—thought to be cyanide-free at the time. Preliminary evidence from the grouper fishery in Coron, Philippines, indicates that a similar market premium is beginning to operate in live food-fish markets.

Governments therefore need to formalise and publicise their certification process, both at home and abroad. For the aquarium-fish trade, this could be done at the industry's conventions, and in its trade magazines. Food-fish importers, mostly in Hong Kong and southern China, are less organised and less concerned about the environmental impacts of their trade, but this situation is likely to improve over time, as it did in the aquarium trade during the 1980s. Already, the Hong Kong Fisheries Department, The Nature Conservancy, World Wildlife Fund–Hong Kong and other groups are working to raise consumer awareness.

Partnerships with the private sector in live-fish importing countries are also important for slowing cyanide fishing. The best current example of such a partnership is the newly-formed Marine Aquarium Fish Council (MAFC) in the United States, which is the single largest market for Indo-Pacific aquarium fish. In 1996, a number of US conservation organisations and aquarium trade groups met to develop the MAFC as a body that would serve as an industry-independent governing council to establish standards and oversee environmental certification of aquarium fish imports and sales in the United States.

Composed of aquarium-fish importers, scientists, and environmental NGOs, the MAFC will establish standards for certifying aquarium fish with reference to collection methods, suitable and non-recommended species, size limits, holding and transportation methods, and other standards of practice. Costs would be borne by a percentage of the sales price, although grant funding would have to cover start-up costs to develop and test applicable certification procedures. Actual certification would be carried out by certification institutions accredited by the MAFC and adhering to the MAFC standards, not by the MAFC itself. The MAFC would require that collectors, traders and retailers adhere to all standards continuously and would identify appropriate enforcement mechanisms, including the monitoring of the chain-of-custody from reef to retailer. The council would work closely with the American Marine Life Dealers Association to reach more retailers and consumers.

Phase in a legal requirement that all live reef-fish imports be certified as cyanide-free

When live-fish exporting countries require cyanide-free certification for all exports, as the Philippines is about to do, importing countries should reciprocate by requiring all live-fish importers to provide certification from the source-country government that the fish they are importing have been certified as cyanide-free.

Since Indonesia and other exporting countries do not currently have testing and certification systems in place, it is probably unrealistic for importing countries to immediately impose a ban on imports of non-certified live fish. But importing country governments, and importers, can move in this direction by gradually phasing in a prohibition on non-certified live-fish imports, simultaneously working with exporting countries to develop testing and certification procedures, laws, and technical capacities.

Importing governments will also need to establish cooperation with groups such as IMA and the Marine Aquarium Fish Council (discussed below) which can provide independent, third-party monitoring of the certification systems that national governments set up.

Provide donor assistance to live-fish exporting countries to help them combat cyanide fishing

Live-fish importing countries that are providers of development assistance (such as the United States, Canada, Japan and the countries of the European Union) should offer financial and technical assistance to exporting countries, to assist them in developing cyanide-fishing reform programmes and certification procedures. The Asian Development Bank has set a good example in this regard, providing some US$ 2.7 million for the Philippines' CFRP as part of a new Fisheries Sector Loan slated for implementation in early 1998. The US Agency for International Development is also providing support for the Philippines CFRP, and is currently developing anti-cyanide fishing activities as part of its Coastal Resources Management Project in Indonesia, in collaboration with IMA.

Strengthen consumer awareness about the impacts of cyanide fishing

As in other areas of environmental certification, it is crucial to build consumer awareness. Where consumers themselves increasingly demand assurances that the fish they are buying have not been caught with cyanide, the pressures to take action on live-fish exporters and the governments that regulate them will grow rapidly.

It is important to note that **testing of live-fish imports on their arrival in importing countries is not an effective strategy, and is likely to be counterproductive.** Cyanide metabolises out of fish relatively rapidly, and tests conducted at import destinations are likely to be negative for cyanide, regardless of whether the fish was caught with cyanide or not.

4. Community-based strategies

Without fishermen in the equation, there is simply no solution to the cyanide-fishing problem. There is no policy, law, or technology that can replace the need to work directly with cyanide fishermen. Training, community organisation, income enhancement, and establishment of community-based coastal management systems in communities currently using cyanide—or vulnerable to its introduction as a live-fish trade is established in their area—form the core partnership necessary to end cyanide fishing.

Train fishermen in cyanide-free fishing technologies

When fishermen are presented with effective cyanide-free technologies for capturing live-food and aquarium fish—and given greater awareness about the legal, health, and ecological risks of cyanide fishing—many choose to convert to cyanide-free techniques.

In the Philippines, IMA has trained over 2,000 cyanide fishermen in cyanide-free live-fish capture techniques. A typical one-week local training programme targets 20–30 fishermen who are currently using cyanide to catch either live food or aquarium fish and have developed an interest, whether through IMA awareness activities or their own experiences, in learning cyanide-free techniques.

Initially, three-day on-land 'classroom' sessions provide lectures and discussions concerning the arguments in favour of cyanide-free fishing, cyanide-free technologies, post-harvest management of catches, cooperative marketing and other strategies for adding fisheries production value, and safe diving techniques.

These sessions are specialised to address specific types of live-fish capture. Fishermen who primarily collect aquarium species are trained in the use of fine-mesh barrier nets. Fishermen for whom food fish are the target species are trained in hook-and-line techniques for capturing groupers and, importantly, simple techniques for decompressing the air bladders of captured fish to ensure their post-harvest survival and health. Because particular grouper species favour distinctive bait sizes and shapes, bait preparation is a key part of the hook-and-line training as well.

Following the 'classroom' sessions, the fishermen and trainers carry out four days of in-water training in either net or hook-and-line techniques. The intensive one-week training is followed by a three-week follow-up period of monitoring by the trainers to ensure that trainees have mastered fishing techniques and proper post-harvest care. Other activities, such as organising local fishing associations and cooperatives and developing value-added livelihood activities—discussed below—take more time and involve periodic follow-up participation by the trainers over months or years.

Using this basic model, IMA in 1997 expanded training programmes to many new areas of the Philippines and now operates such programmes in five major cyanide-using regions. IMA has also initiated the first Indonesian training programme, for 60 fishermen, in North Sulawesi province, working with a local partner organisation.

Enhance local income from the live-fish trade and other sources

Fishermen's incentives to forsake cyanide fishing increase—and partnerships between fishing communities and outsiders such as IMA grow stronger—when local income from sustainable use of marine and other local resources rises. Beyond training in cyanide-free fishing techniques, IMA therefore works with fishing communities to promote a variety of livelihood enhancement activities.

When fishermen can get more money for cyanide-free live fish, they are extremely enthusiastic about converting to cyanide-free techniques. As in most poor fishing communities in South-East Asia, cyanide fishermen receive only a small percentage of the value of their catch, with the lion's share of profits accruing to middlemen. By helping fishermen obtain post-harvest equipment and know-how and assisting them develop their own marketing cooperatives and outlets, the local share of the profits can be increased.

In the area of North Sulawesi, Indonesia, where IMA initiated a training programme in July 1997, for example, the local partner organisation is the provincial cooperative of retired military veterans. By providing the fishermen with diving compressors (previously, the only one in the village was owned by a live-fish broker with a local monopoly on the trade) and offering higher prices for fish through the cooperative, the programme will break the power of the middleman and help the fishermen obtain higher prices for the cyanide-free aquarium fish they capture. The cooperative itself sees a good business opportunity, of course, but perhaps as important, the cooperative's director is also a dive-tour operator concerned about the effects of cyanide on the reefs which have made the province a premier dive destination.

Few fishing communities, however, subsist wholly from the live-fish trade. More typically, they pursue a 'portfolio' economic strategy combining live fish, fresh and dried fish, agriculture, wage labour, and other activities. An effective livelihood enhancement strategy needs to target all of these activities, and introduce new ones where an opportunity exists. Introduction of simple technologies can often add significant value to products that communities are already harvesting and selling. In Philippine fishing communities where the capture and sale of tiny dried fish (*dilis*) is a common activity, teaching simple techniques to spice the fish can raise their value by 40 per cent. Where raw oysters are collected, teaching oyster-sauce production methods adds considerable value to that product. In some communities, IMA training programmes promote non-fishery activities, such as soap making, tailoring, and handicrafts production. In short, the IMA training and livelihood enhancement strategy seeks to assist a larger socio-economic transformation of poor fishing communities towards a better standard of living based on sustainable resource use and capturing a larger share of the local profits for local benefit.

Strengthen community-based management of local fisheries and reefs

Partnerships with fishing communities must go beyond training and income enhancement, important as these elements are. Sustainable coastal management requires the participation and support of the local communities that directly earn their living from the sea, in cooperation with government agencies—an arrangement often called 'co-management'. Cyanide fishing, blast fishing, coral mining, mangrove destruction, and many other sources of coastal degradation can only be slowed when the communities on the front line become central players in protection efforts and beneficia-

Toward a cyanide-free fishing tradition on Canipo Island, Philippines

Canipo Island is located in the Calamianes group of islands in the north of Palawan Province. The area has been a traditional fishing ground for live grouper collection, especially the high-priced spotted coral trout (*Plectropomus leopardus*). For years, hundreds of fishermen used sodium cyanide to collect groupers. In 1993, however, a local businessman engaged in live grouper collection and, dismayed at the impacts of cyanide on the reefs, started a cooperative called Kawil Amianam—Filipino for hook-and-line collecting. The group used the traditional hook and line, but also developed a method using a plastic straw for decompressing the air bladders of the captured fish, which is necessary for the fish to survive when they are rapidly brought from 20–25 m to the surface.

More than 400 fishermen in the area soon joined Kawil due to pressure from the Cyanide Fishing Reform Program (which began operations in the area and opened a Cyanide Detection Test liaison office in 1994); urging by their peers already in the group; and the fact that Kawil's decompression method exploded the long-standing myth: you can't catch live groupers with a hook and line. In 1994, the Kawil fishermen began having samples of their catch tested by the CDT lab in Manila, with assistance from the CDT liaison office. Fish sampled by the liaison office were sent to Manila by air and tested. The results (in the form of certification that the tested fish was cyanide-free) were returned to the Kawil members within 36 hours, so as not to unduly interfere with shipping of the catch.

In 1995, IMA started working with Kawil to train more fishermen in the area and to assist in modifying the bladder-decompression technique and tools, substituting less stressful large-gauge hypodermic needles for sharpened plastic straws. The Kawil hook-and-line and decompression technique is also being transferred to other areas of the country via training programmes. Sampling and testing of Kawil's catch has continued for the past two years, and the test results indicate that virtually all members of the group are continuing to use the hook-and-line method and have not reverted to cyanide use.

Major reasons for the preliminary success of the cyanide reform effort in the Canipo area seem to be 1) dedicated and persuasive leadership of the fishermen's organisation; 2) the fact that fishermen receive a higher price for cyanide-free groupers; 3) the presence of CDT sampling and monitoring personnel in the area; and 4) the self-policing of its members carried out by Kawil.

ries of sustainable management. This requires policy shifts by most governments, which have traditionally treated coastal zones and fisheries as the exclusive preserve of state power and policy.

In some areas of eastern Indonesia and the western Pacific, long-standing customary systems of marine tenure and management provide a sound institutional basis for community-based efforts. Where they exist, governments should recognise and support these customary systems and provide technical and financial inputs to assist traditional communities in adapting to rapid economic and technological changes.

Most coastal communities in South-East Asia, however, do not possess functioning customary systems for managing and conserving coastal resources. Many are comprised of a heterogeneous mix of immigrants and natives who lost such systems long ago. This loss does not mean that viable community management systems cannot be nurtured. The Philippines, where customary coastal management systems have vanished, has the most extensive and active community-based coastal resources management (CBCRM) initiatives in Southeast Asia.

A successful CBCRM programme requires government commitment in policy and law, collaboration with like-minded donors and NGOs, and a 'learning process' of drawing on the ideas and innovations of local communities to establish, refine, institutionalise, and measure the accomplishments of CBCRM initiatives.

Build the capacity of local communities to serve as front-line agents in anti-cyanide monitoring and enforcement

Building on training, community organisation, and livelihood enhancement initiatives, an effective cyanide-fishing reform programme needs to enlist local communities as partners in the specific tasks of monitoring and enforcement. Local fishers are on the water far more regularly and know their areas better than government fisheries officers. With minimal training, which NGOs are often best equipped to provide, these groups can serve as an 'early warning network,' letting officials know when cyanide fishermen appear in an area. In the Philippines, members of local fishermen's organisations and cooperatives have been deputised as 'fish wardens' to patrol and monitor their fishing grounds.

Although local community groups cannot be expected to directly confront well-organised—and often well-armed—cyanide-fishing vessels, they can perform important norm-setting and self-policing activities within the community. After all, a 'community' does not decide to renounce cyanide fishing. More often, one group of individuals within a community may make that decision, while others continue using cyanide. Peer pressure is thus important in spreading the cyanide-free tradition throughout the community.

5. Conclusion

Cyanide fishing is not the only threat to the coral reefs and other coastal ecosystems of the Indo-Pacific region. Other threats include rapid conversion of coastal habitats such as mangroves for aquaculture, charcoal, and building materials; overfishing due to government-subsidised fleet over-capacity; dynamite fishing; haphazard coastal tourism development; runoff from industrial pollution, mining, urban wastes, fertilizers and pesticides; and sedimentation arising from deforestation. But the training and community-organisation strategies essential to stopping cyanide fishing also provide an important catalyst for communities to address a broader range of threats to their local reef environment. And four unique characteristics of cyanide fishing provide hope that it can be stopped or at least significantly reduced faster than some of the other threats to coral reefs:

- Cyanide fishing is generally focused on isolated reefs far from the effects of coastal habitat conversion and sedimentation. As a result, the problem is relatively localised and a discrete target for control efforts;

- First discovered in the late 1950s, cyanide is a relatively recent fishing technique and has only come into widespread use in the past three decades in the Philippines, much more recently in other countries. Outside the Philippines, therefore, the practice is not yet deeply embedded in local cultures and economies;

- Cyanide fishing targets a very specific and 'high-end' market—live food and aquarium fish—with some food species selling for as much as US$ 180 per kg and some aquarium species fetching US$ 350 per individual. The consumers and their suppliers are therefore an identifiable and fairly limited group;

- As detailed above, there is a clear and not-too-complicated set of actions to address the problem if governments set the right incentives in place, and partnerships are developed among fishing communities, exporters and importers of live-fish, scientists and NGOs.

The difficulties in stopping cyanide fishing should not be underestimated. It is important to note, though, that people have long captured and sold live fish without using cyanide, and they still do in many places such as the Caribbean and Hawaii, where live aquarium fish have been collected with fine-mesh nets for decades. Nothing is intrinsically wrong with a cyanide-free live-fish trade as long as it is practised at sustainable levels, and protects the coral reef ecosystem that provides fish habitat. But cyanide fishing is fast becoming a deadly tradition in the Philippines, handed down from father to son. It will soon be just as firmly established in Indonesia and other countries throughout the Indo-Pacific. Our challenge is to eradicate the growing cyanide tradition and replace it with a cyanide-free fishing tradition.

For more information on cyanide fishing and strategies to combat it, contact:

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36 Santa Catalina Street, Barangay Kapitolyo
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Tel: (63-2) 633-5687; Fax: (63-2) 631-9251;
Email: imaphil@mnl.sequel.net

Pacific Islands target live reef fisheries management

The 6th South Pacific Conference on Nature Conservation and Protected Areas (the premier regional and international event for nature conservation in the Pacific Islands region) was held in Pohnpei, Federated States of Micronesia (FSM), from September 29 to October 3, 1997. It was co-ordinated and run by the South Pacific Regional Environment Programme (SPREP) and hosted by the FSM National and Pohnpei State governments.

The outputs of the conference included revisions to the 'Action Strategy for Nature Conservation in the South Pacific Region 1994-1998' for the coming four year period, a TOOLBOX based on the results of the various working group sessions, and a number of resolutions adopted by the Conference. A full report of the meeting should be available later this year from SPREP, PO Box 370, Apia, Western Samoa. E-mail: sprep@pactok.peg.apc.org

One of the resolutions was focused specifically on the live reef fish trade in the Pacific islands region. The resolution reads:

Resolution 5: Control and management of the live reef fish trade in the Pacific Islands region

The Sixth South Pacific Conference on Nature Conservation and Protected Areas:

NOTING with concern the destructive impacts of the live reef fish trade and associated use of sodium cyanide on the environment, economies and rural communities of Southeast Asia and some Pacific islands;

RECOGNISING the real threat to Pacific reefs due to the uncontrolled expansion of the live reef fish trade, and associated use of chemicals and illegal fishing methods;

REALISING the importance of coral reefs to Pacific island communities for subsistence, economic and cultural needs;

NOTING that this is the Pacific Year of the Coral Reef;

MINDFUL of the continued increase in demand for live reef fish for the aquarium and restaurant trade, and the potential long-term value of this trade to Pacific island reef fisheries, if properly managed:

REQUESTS that SPREP inform its member governments of the potential environmental impacts of the uncontrolled expansion of the live reef fish trade within the region; and

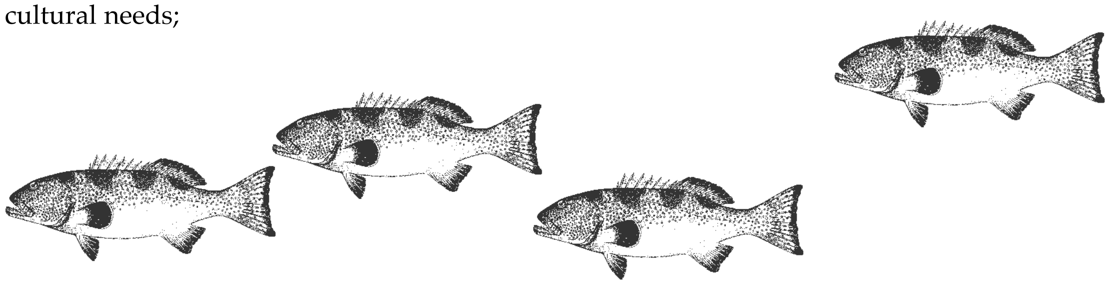
URGES SPREP to work in partnership with other relevant regional agencies (such as the SPC Fisheries Programme), and appropriate public and private organisations and individuals to:

- Encourage and assist SPREP member governments to recognise this fishery regionally and nationally as one requiring careful and separate management, monitoring and strict enforcement;

- Undertake effective programmes of resource protection and monitoring particularly for protection of grouper aggregation and spawning sites;

- Encourage and assist the establishment of a regional three year moratorium on the export of Napoleon wrasse (*Cheilinus undulatus*) to permit research to be conducted on its life history, and develop appropriate management and protection strategies for this species; and

- Implement educational awareness programmes to enable more informed decisions on issues relating to this trade and encourage reef-friendly fishing methods; and to encourage certification programmes that ensure the sustainable capture of live reef fish.



Doomed fishermen

by Michael Jacques

This article is condensed from the magazine Pacific below. *In it, Michael Jacques describes the almost suicidal diving practices employed by the live reef fish divers he and his companions encountered near Dangar Island, near Sumbawa, eastern Indonesia. Jacques rightly stresses the need for education. In the article that follows this one, Johannes and Djohani relate their encounter with a bent live fish diver and his community, which suggests, however, that education alone will not always be the answer.*

Suddenly we were cold and wet, working sails and sheets. Dangar Island and the stark relief of Sumbawa beckoned us. We crept into a small anchorage just SW of Dangar Island. We found ourselves surrounded by jagged low peaks. Surveying the scene we noticed outpost holding tanks for the live fish trade, suspended by drums and bamboo. We saw and heard the boats returning to the Bugis village. The original Indonesian seafarers, and occasional pirates, these people had transmigrated some time ago from South Sulawesi and established themselves in this massive, rich bay known as Teluk Saleh.

Here they encountered a new and unfamiliar adversary.

It came from the North, bringing with it commercialism, materialism and greed. It came in the form of wealthy financiers seeking to fill the restaurants of Singapore and Hong Kong with prized live reef fish species attracting incredible prices in those countries, and creating more individual wealth. We knew it had a disregard for the fish and the reef that sheltered them.

We were soon to find out, first hand, that this disregard extended to human life as well. Samsara visited early the following morning, preceded by the splutter of his motor. He eyed us curiously, and when beckoned to come aboard in a familiar tongue, he joined us. He had been fishing all night. His story-filled hands eagerly accepted strong coffee, to which he added the traditional half kilo of sugar.

His face shrouded in a black balaclava, he told us how he came to be in Teluk Saleh. He told us of his catch, his life and his family. He told us of the reef, the fishing, and marvelled at our charts of his home. Significant to this story, he told us of the live fish trade, where to find the divers, and, darker side, human cost.

We upped anchor, following Samsara's directions, beginning what turned out to be a very short search for the live fish divers. Rounding a small headland, were greeted by a massive sparkling bay. Dotted all over the bay were small boats, compressors chugging, their bright yellow hoses snaking into the sea.

We approached one boat. Our polite question of 'can we dive with you?' was met with a firm no, and a tug on the hose bringing the diver to the surface. The boat quickly moved off to another location. We decide to assemble equipment and cameras in an attempt to generate a little more curiosity. Apparently this was what was required. The next team, slightly younger, greeted our suggestion with enthusiasm, eager to display their diving prowess.

Taking a closer look at their vessel we noted it was completely open. A small tank housed the catch. The boat was made of fibreglass and numbered as part of a fleet of similar vessels. A surface supply unit was situated aft of the holding tank. This was obviously part of a well-organised, well-financed operation. We determined that the divers were working in teams of two, alternating diving and tending the compressor.

The water was heavily silted, shafts of light strobed downward. Only our depth sounder indicated that the bottom lay 60 to 90 feet (20 to 30 metres) below us. We donned our equipment. The contrast between our gear (the latest in buoyancy compensating devices, decompression computers and safety equipment) and that of the Indonesian divers (a mask with hose fitted into it, surface supply unit, lead sheet wrapped around rope, shorts and T-shirt) was truly eye-opening.

We descended below the vessel, and waited, the bottom contours coming into view. The coral reef fringe joined a dark silty seabed of volcanic origin. It was along the edge of the reef that we noticed the wire traps camouflaged with broken coral, the intention being to provide an enticing cave for the territorial fishes the fishermen were seeking.

We descended to the trap, the first of a series of traps placed along this area of reef. Upon closer inspection, we noticed that a large sailfin snapper had beaten itself to death in the cage.

Out of the gloom came the diver. He came like a torpedo, straight down, his finless feet and the overweighted belt propelling him toward the bottom. Bubbles poured from his mask as he inspected the trap. He removed the dead fish and just threw it away. It sank slowly, resting forgotten on the bottom.

I was dismayed. Although the fish was dead, it still would have fed a small family. It appeared to have no value. He lifted the heavy steel trap and literally sprinted across the bottom, his bare feet churning up silt, searching for a new location.

Upon finding a satisfactory area, he placed the trap, and began swimming over to the reef edge. From here, he gathered broken coral, or selectively broke coral to disguise the trap.

My attention was no longer on the environmental issues and wastefulness of this industry. We were at 70 feet (23 metres)! I was watching the diving practices, and my mind started churning through diving physiology. Rapid descent, heavy workload, CO2.

How many descents had he already made? How rapidly was he going to ascend?

Suddenly, the trap baited, he was gone, moving quickly on to another trap. I checked my AIR X computer, and thought 'these guys must be dying here'.

The diver repeated the process. I was obliged to help. I knew clearly the rate at which nitrogen was dissolving into his blood. And I suspected that a decompression stop was unlikely. My suspicions were confirmed a moment later.

The diver tugged on the hose, gripped it firmly, and was dragged rapidly towards the surface, frog kicking all the way. I began to follow, my computer screamed a rapid ascent alarm.

I stopped, and rejoined Stefanie, who had been concentrating on photo-documenting the scene. We looked at each other and ascended as we had been trained.

During our safety decompression stop below the fishing boat, my mind was racing. What would a hyperbaric medical specialist discover down here with an extensive study? Both of us were aghast to hear a splash, and see the same diver plummeting downward with a new trap. Moments later he was back, glancing at us as he surged by.

We surfaced in brilliant sunlight. Both crew members were on the boat and our companions looked on from *Longnose* in amazement. The sea was warm and flat.

We hung from the gunwhales of the fisherman's boat and began asking questions. The compressor was shut down. The only sound was the chug of other compressors nearby. We spoke loudly. Obviously, the inability to equalise one's ears was not a barrier to working. I wanted to have a look at those ear drums, or what was left of them.

I felt obliged to attempt to pass on some safe diving practices immediately, and to find out more.

How long had they been working today?
Since first light.

How many times had they dived?
Don't know. We take turns.

How much longer would they work today?
Until we are finished.

I was no longer as interested in the environmental aspects of this industry as I was now certain there was a human cost. Inwardly, I was angry, and ashamed of my species. The picture was becoming all too clear.

Who taught you to dive?
The company provided the boat and told us to keep breathing.

Did they tell you not to dive too much? To go up and down slowly? To stop on the way up?
No, they told us how much money we could make.

How much money can you make?
10,000 rupiah (US$ 5) a kg for the best fish, if alive.

How many kilos a day do you take?
Don't know. They give us the money.

Are you tired at the end of the day?
Yes, very tired.

Do you feel sick?
Sometimes sleep is difficult. But I feel better the next day.

Has any other taught you about decompression illness? I was greeted with blank looks. I described the symptoms.

I was reluctant to say too much. I knew that these men were feeding their families through this industry. I knew they would continue. I wasn't sure it would help them to be scared of their work. I decided to concentrate on providing ideas on a safer method of laying and retrieving the traps. I wanted to explain staging fish, and piercing swim bladders, so more of the catch would live.

Before I could begin the elder of the two spoke ... I will never forget his words. I am sure that he is not alone in his recollections.

He said very matter-of-factly: 'Sekarang saya menarik, karena kemarin, teman saya, dia tidak bilang apa apa. Dia mati saja'.

A rough translation equates to this:

'Now I am interested because, recently, my friend, he didn't say anything, he just died'.

I was not surprised. I was upset. I wondered how many others had died or been damaged by the greed of an invisible financier. We spoke some more about ascent and descent practices, about the use of ropes and rope signals to raise and lower traps. I was trying, but they wanted to move on to their next set of traps.

We asked if we could follow. They were happy to have us join them. In the next two hours, we were in and out of the water, taking turns trying to keep up with these men. It became clear they didn't know where exactly their traps were. They were using rough triangulation in order to locate reef edges, and hence their traps. They couldn't mark them, because someone would steal their fish, or traps, or both.

I saw one diver do nine ascents and descents to an average depth of 60 feet (20 metres), at a speed varying somewhere between dangerously fast, and the speed of light—all this in 90 minutes. I didn't see him retrieve one live fish in that time. Numerous other boats were repeating the same procedure at other locations around this huge bay. We took photo after photo. We took turns to dive into the murk. We knew these people must be suffering decompression illness. We knew that some of them were dying. We knew that the people proving the equipment and the financial incentive obviously didn't give a damn!

Eventually, we decided we must leave to seek a safe anchorage on the north side of Moyo Island.

This is such a difficult situation. There are so many factors to consider.

This industry undeniably provides an income for the people of the region. It gives them an opportunity to make good money quickly, and provides the foundations of their children's future. It is highly likely they may never live to see the future with their children, however.

In an ideal world, the industry would be outlawed. This is not an ideal world. The fact remains that while a demand exists for live fish, and the profits are so great, people will continue catching them.

Historically, divers have placed themselves at risk due to lack of knowledge. As we approach the millennium, this is no longer necessary. Financiers should have the human decency to educate the divers, allowing them to continue making a living in reasonable safety. From a humanist perspective, if it is to continue, it has to be in a responsible manner.

From an environmental aspect it should be stopped.

Environmentally, this industry cannot continue in its present form. The fish are territorial. Mating populations are being decimated. The yields are on the decrease. Corals traumatised by such rough handling do not rebound well, disrupting the fragile ecosystem of the reef. Ultimately, the environmental damage is being borne by all of us, for the momentary culinary gratification of a few.

The Indonesian government continues to publically denounce unsustainable fishing practices, but the answer lies in the nations where these fish are ultimately sold. The answer lies with the people who are buying them. The sale of live wild fish could easily be declared illegal. As should the purchase. The penalties should be heavy, because the environmental costs and the human costs are high. I am not offering a solution to the economic problems of isolated island communities. I am all too familiar with the dilemma of subsistence lifestyles. The problem lies not with these people who, some times at a great personal cost, catch these fish. It lies with the people who are financing the industry at great personal gain. The solution lies with the people who demand the fish, and the governments of the nations where the fish are proudly displayed, and sold at great profit, without concern for the real costs.

Source: *Pacific below*

Reducing the incidence of the bends in Indonesian fishing villages: Education may not be enough

By R.E. Johannes & Rili Djohani [1]

Thousands of divers have been paralysed and hundreds killed in the past several years in the Philippines and Indonesia as a result of the bends (Johannes & Riepen, 1995). The accidents occur when divers go down too often or too deep and/or stay down too long in pursuit of pearl shell, aquarium fish, lobsters or live reef food fish. The frequency of such accidents is said by divers to be increasing as they find themselves forced to go deeper and stay down longer after having depleted stocks in shallower waters.

Johannes and Riepen (1995) report that the fishermen are often informed poorly, or not at all, concerning the cause of the bends (see also the preceding article in this Information Bulletin by Michael Jacques). It might therefore be inferred that education is the key to greatly reducing the bends among divers in this region. Additional interviews we carried out in the Komodo region of Indonesia in May 1997 reveal that a more complex cause can underlie this problem.

Here, we found that divers were at least broadly aware of the dangers and causes of the bends. But diving is looked upon by boys and young men between about 15 and 25 years of age as a romantic and 'macho' activity. Moreover, just like teenage car drivers in western countries, they assume that 'accidents happen to other people' as they push beyond the safe limits.

Greatly reinforcing this willingness to risk their lives is another factor: chronic debt. Typically hookah gear and associated equipment cost about 20 million rupiah (roughly $US 800), a sum that is well beyond the means of the majority of divers. So, to get their start, they borrow the necessary money from middlemen who buy their catch. The latter then put pressure on them to repay the debt as quickly as possible, sometimes accompanying them on their trips and urging them, we were told, to make four dives a day for an average duration of 40 minutes at depths of up to 45 m.

A serious non-lethal case of the bends typically involves paralysis from the waist down, from which the diver may recover completely, partially or not at all. We interviewed one 17 year-old-boy who had been stricken by the bends only 24 hours earlier. Frightened, sweating profusely, he was paralysed from the waist down, unable to control his excretory functions and unable to feel his legs or feet.

He knew that there was a possibility that he would not recover. Yet when asked if he would go back to diving if he did recover, he answered unhesitatingly that he would. Older villagers did not approve of this attitude but said that it was common and that they felt helpless to do anything about it. 'Once you are in debt and your middleman says "dive", you have to dive', said one. Middlemen, it was pointed out, have nothing to lose when one of their divers is injured or killed. They simply repossess the victim's diving gear and resell it, sometimes at a profit, to pay off his debt.

Some villagers volunteered their (correct) belief that fatigue or alcohol consumption increases the likelihood of getting the bends. Yet, they said, young divers often went when tired from previous dives, and drank beer to help them warm up between dives.

One village leader told us that, if we volunteered to teach their young men more about the bends, the village would certainly agree, but only because they thought such education might be marginally useful. The real problem, they said, was lack of alternative employment opportunities. If a diver was lucky enough to be able to repay his debt and owned his diving gear, the incentive to exceed safe diving standards was significantly reduced, they said.

In order to try to reduce such dangerous diving practices in the Komodo region, as well as associated destructive fishing practices described by Jos Pet in the previous issue of this publication, The Nature Conservancy is working to develop various alternative employment opportunities. These include tourism, pelagic fishing for Spanish mackerel and aquaculture of groupers, abalone and sea cucumbers.

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1. The Nature Conservancy, Jakarta

How fresh is too fresh? The live reef food fish trade in Eastern Indonesia

by Mark V. Erdmann [1] & Lida Pet-Soede [2]

Although the live reef food fish trade has become an increasingly 'hot' topic in the environmental press in recent months, many of the sources reporting on this practice have tended to focus on issues related to the rampant use of sodium cyanide in the trade rather than the more pressing matter of the looming potential for overexploitation engendered by this practice. We present here a brief overview of the live reef food fish trade as it is practised in Eastern Indonesia—the methods used and the economics, geographic extent and numerous deleterious effects of the fishery—in order to demonstrate the rather dire situation facing the countries which allow this extremely unsustainable practice to continue in their waters.

The live fish trade

The live reef food fish trade is fuelled by the heavy demand in Hong Kong, Singapore, Taiwan, mainland China, and other Chinese centres for the 'ultimate' in fresh fish: those which are selected live from restaurant aquariums only minutes before eating. Such fish are highly priced not only for their freshness and flavour, but also for their reputed virility-enhancing and overall health-promoting qualities. The target reef fish species include rock cod and groupers (*Epinephelus* spp.), coral trout (primarily *Plectropomus* spp., but also *Cephalopholis* and *Variola* spp.), barramundi cod *(Cromileptes altivelis)* and the Napoleon wrasse *(Cheilinus undulatus)*. Non-reef species such as the sea bass *(Lates calcarifer)* are also part this trade but will not be further considered in this article.

The prices paid for these highly prestigious fish are extraordinary: a single, large 40 kg Napoleon wrasse can sell for over US$ 5,000, including up to US$ 245 for the lips alone! Napoleon wrasse and barramundi cod are the two most sought-after species, followed by the more common coral trout and grouper species. R. Johannes and M. Riepen report that on average live reef fish fetch prices 400–800 per cent higher than identical, but dead, fish in Hong Kong. The economic rewards of this fishery are alluring to fishers and business persons alike; each year the ranks continue to swell as more companies are enticed into the business. The trade now stretches from the Maldives to the South Pacific Islands, with the Philippines and Indonesia supplying the vast majority of the fish to date. According to industry representatives, stocks in these two countries are expected to collapse within a few years, after which the trade will focus increasingly on Papua New Guinea and the Pacific Islands.

Capture of the fish by stunning them with cyanide solution is the most common method. In addition to cyanide fishing, significant numbers of live fish are captured using hook and line, fish traps, or nets. In Indonesia, fish are collected by two types of fishers: individuals working alone or in small groups in locally modified boats, often with loaned equipment/cyanide, and by well-organised teams of divers working from large 'catcher' ships equipped with 6–10 fiberglass dinghies and live-hold tanks that can accommodate 1–2 t of live fish. Such vessels can range much further afield than small boats, although both types deposit their catch in the same holding cages at central collection points. Fish then await collation into volumes large enough to justify pick-up and transfer by large transfer vessel ('storage' times can vary from only two weeks in the largest collection centres like Ujung Pandang and the Moluccas, to four months in smaller areas like the Togian Islands). Hong Kong is the primary destination for fish caught in Eastern Indonesia, although increasing volumes are now transshipped to mainland China as well.

Economics of the trade

A mentioned above the prices fetched for live fish make the trade irresistible to many South-East Asian fishers. Table 1 summarises the price structure for the most commonly targeted live food fish species, with a comparison to the most expensive chilled export species in Sulawesi, Indonesia. The figures are illuminating: fishers make 2–25 times more for live fish than for comparable dead ones, and the price roughly doubles at each step up in

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Table 1: **Prices of selected live fish for fishers, local exporters and wholesalers/restaurants, 1995. All prices are for Sulawesi, Indonesia, unless otherwise noted. Restaurant prices are scarce in the literature and are therefore grouped with wholesale prices.**

Species	Fishers (US$/kg)	Local exporters (US$/kg)	Wholesale/ restaurants (US$/kg)
Epinephelus spp., *Plectropomus* spp., and *Cephalopholis* spp.	5–12; 12 [1]	25	70–100 [2]
Cromileptes altivelis	20	50	90–150 [2]
Cheilinus undulatus	20–25	50	90–180 [2]
Scomberomorus commerson (chilled export)	2	3–5	—
Unspecified grouper (chilled export)	1–5	5–7	6–25 [2]

Sources: [1] Philippines (Pratt, 1995); [2] Hong Kong (Johannes, 1995)

the business. For fishers, these are heady incentives; we calculate that fishers in the live trade receive US$ 150–500/month, which is 3–10 times the average monthly salary of artisanal fishers, and 1–3 times that of university lecturers! Local fish exporters can also make enormous gains, although many new ventures end in bankruptcy in this highly secretive and competitive business. The success of local businesses hinges on preventing high fish mortality; a well-managed cage operation with proper antibiotic/antifungal treatment, proper feeding, and optimal fish densities can maintain mortalities at a modest 10–25 per cent. However, inexperienced operators can suffer up to 100 per cent mortality due to rough capture/handling of the fish, inadequate shading of the cages, heavy wave damage, overfeeding, overcrowding and exceptionally long storage times.

Accurate figures for the volume of live fish trade are extremely elusive; many exporting countries such as Indonesia have no official records for the live trade, while importing countries such as Hong Kong can only provide statistics for gross weights of air/land shipments. In by far the most comprehensive study of the trade to date, Johannes and Riepen (1995) estimate that the total annual volume of wild-caught live reef fish food traded in the Asia/Western Pacific region is 11,000 to 16,000 t, with Indonesia supplying roughly half of that volume in recent years. Although we cannot comment on the accuracy of their overall figure, our best estimate of total annual Indonesian live food fish exports is only 2,200 t for 1995, based on extensive interviews/ personal observations throughout Eastern Indonesia. This figure is substantially lower than the Johannes and Riepen report, and is only 33–66 per cent of the figures reported for Philippine exports in 1995 (Table 2) (But see addendum to this article).

Similarly, an evaluation of the relative significance of the live grouper trade to the overall grouper fishery in Indonesia gives conflicting results. In Ujung Pandang (one of the largest collection points for the live fish trade in Indonesia), the annual export volume of live groupers for 1994/1995 approximately equals the annual volume of dead groupers landed in 1993 (Table 2). While these figures are not completely comparable, it should be noted that a substantial percentage of the dead groupers landed is simply dead fish from the live cages. As such, it seems reasonable to suggest that for Ujung Pandang, the live grouper trade equals, if not surpasses, the traditional grouper fishery. The situation is different if one examines figures for Indonesia as a whole. Official government statistics record 21,757 t of dead grouper landed in 1992, ten times our estimates of the live food trade. These figures appear to relegate the live grouper trade to a less significant position within the overall grouper fishery.

Deleterious effects of the live fish trade

Grouper and other reef fish have traditionally supported important fisheries in many countries; the

Table 2: **Annual volumes of selected fish exports from Ujung Pandang, South Sulawesi, Indonesia and the Philippines**

Area and type of fish	Amount exported (t)
Dead grouper from Ujung Pandang (1993)	305 [1]
Live grouper from Ujung Pandang (1994/1995)	306 [2]
Live grouper from Indonesia (1994/1995)	1,870 [2]
Live reef fish from the Philippines (1995)	3,000 [3]; 6,000 [4]

Sources:
1. Official statistics.
2. Based on overall estimate of 360 t/year for all live reef fish exports, Ujung Pandang and 2,200 t/year for Indonesia. Of this, groupers comprise approximately 85% (35% *Epinephelus* spp., 45% *Plectropomus* spp., and 5% *C. altilevis*); *C. undulatus* is roughly 15%.
3. Based on exports for January–October 1995 (Pratt, 1995).
4. Based on exports for January–July 1995 (Johannes, 1995).

recent trend towards maintaining them alive can hardly be considered unfavourable in itself. However, certain aspects of the live reef fish trade, as it is practised in most tropical Asian countries, make it an extremely damaging fishery.

The most well-publicised of the negative aspects of the trade is what Johannes and Riepen (1995) refer to as the 'extensive collateral environmental damage' caused by the fishery, particularly by the use of sodium cyanide. Cyanide solution in concentrations used to capture large reef fish has been shown to be lethal to most reef organisms, including smaller fishes, reef invertebrates, and most importantly, the reef framework builders themselves: the hard corals. Filipino fishers and divers alike are increasingly reporting reefs 'treated' with cyanide which are little more than bleached calcium carbonate deserts. In our experience, these reports are somewhat extreme; reefs in Eastern Indonesia which have been positively cyanide-fished often are most conspicuous for the complete absence of serranids (juveniles included) and the curious feature of a ring of dead, bleached coral surrounding virtually every hole in the reef structure. This apparent disparity in the effect of cyanide use is perhaps best explained by the interaction of the different environmental conditions experienced by these reefs; Filipino fishers appear to use much greater quantities of cyanide per unit area than do their Indonesian counterparts, and Philippine reefs may be subject to higher levels of synergistically-injurious sedimentation and pollution than reefs in remote Eastern Indonesia. Regardless, it seems unarguable that cyanide use is harmful to reef communities and deserving of its notorious reputation.

Another potential ill effect of the live fish trade is the possibility of human health problems caused by consuming cyanide-tainted fish. To date there do not seem to be any cases of cyanide poisoning from eating live fish in the importing countries; however, these imported live fish did not receive lethal doses. In Indonesia, those fish which die from cyanide overdose are commonly sold on the local market. These fish would certainly present a greater health risk than the imported fish, but the general lack of health care in fishing communities would presumably inhibit any epidemiological studies on cyanide effects. The effects discussed above related primarily to the use of sodium cyanide, and are certainly noteworthy. However, we believe that the most alarming effect of the live reef food fish trade is irrespective of capture technique; the tremendous financial incentives provided by the fishery are sufficient to ensure that management will be extremely difficult and severe overexploitation of target stocks seems inevitable. The very high prices fetched for live reef fish encourage many fishers to enter the fishery. New fishers have no concept of traditional limits on fishing, and even experienced fishers may be lured by the large amounts of money involved to disregard traditional limits. Export companies provide the capital equipment and infrastructure to allow fishers to exploit remote areas which previously were only lightly fished. The trade is so lucrative that it has spread feverishly throughout Indonesia, opening live grouper fisheries in areas that traditionally concentrated only on pelagic and squid fisheries. Local overexploitation seems imminent; the sedentary nature of grouper species makes them very susceptible to overfishing. The likelihood of cyanide-related side kills of recruitment-limited serranid juveniles only enhances the potential for overfishing.

Despite the apparent logic of the above arguments, it is difficult to demonstrate overfishing caused by the live reef fish trade. On the one hand, anecdotal evidence of overexploitation is abundant: fishers and dive operators are adamant that the live fish business is responsible for 'empty' reefs throughout the Philippines and Indonesia, and industry representatives give several examples of archipelagos which are exhausted; they reportedly give the whole of Indonesia only three more years of financially viable operation. Hong Kong transport vessels which used to make collection visits in Ujung Pandang every two weeks are now much less regular in their schedules. Nonetheless, solid evidence is lacking. The above analysis of the importance of the Indonesian live grouper trade in relation to overall grouper landing does not appear to support assertions of overfishing; a practice which accounts for only 10 per cent of the overall grouper fishery can hardly be claimed to cause overfishing. Even substituting a figure of 6 000 t/year of live grouper exported from Indonesia (as reported by Johannes and Riepen) fails to produce a potentially dominant position for the live grouper trade. The source of this major discrepancy in our assertion versus the above statistics is unclear; nevertheless, we maintain that the live reef food fish trade in its current form has tremendous potential to cause local overexploitation, if not local extinction of target fish species stocks.

Two final injurious effects of the live fish business on local communities are worth mentioning. First, this practice, especially when it involves sodium cyanide use, effectively robs communities of any diving ecotourism potential of their reefs. Dead corals and a lack of large fish are rarely considered diving attractions. Perhaps more importantly, diving accidents are commonplace among divers in the live fish trade. Very few of the local divers employed in the business have any knowledge of diving physics, and nearly 100 per cent of the divers interviewed have suffered at least minor symptoms of decompression sickness. Severe paralysis and even death are not uncommon. Without enforced diver education, these conditions are likely to persist.

Prospects for management

In most of the source countries, the live reef food fish trade is limited to some extent. Most countries prohibit the use of sodium cyanide to catch fish, but enforcement is generally lacking (local officials are either paid to look the other way, or may even be partners in the business). In Indonesia, it is only illegal to use cyanide for fish capture; possession of cyanide on fishing vessels is permitted for 'tranquillising' purposes. Legal loopholes such as this make enforcement virtually impossible. Both the Maldives and Indonesia prohibit or severely limit the capture of Napoleon wrasse. In Indonesia, this restriction is easily avoided by several means: individual operators simply photocopy the difficult-to-obtain permits, and Napoleon wrasse shipments are intentionally mislabelled as grouper (Johannes, 1995). Again, the big money involved in the trade seemingly precludes any significant regulation of the live fish business.

To end on an even more pessimistic note, it seems that even the rapidly developing grouper aquaculture industry is unlikely to provide relief to pressures on wild stock. Johannes and Riepen conclude that 'whatever species remain uncultured will hold special appeal for many Chinese consumers, for whom rarity and "wildness" are major gastronomic virtues…' With such a bleak outlook for the future of this trade, one is tempted to ask the question, 'How fresh is too fresh?'

Further reading

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Source: *NAGA, The ICLARM Quarterly*, January 1996

(see addendum on next page)

Addendum

After discussion with Dr Bob Johannes regarding the differences in our respective estimates of live reef food fish export figures from Indonesia (2,200 t/year by our estimate versus 6–9,000 t/year in the Johannes & Riepen report), we believe the major cause of the discrepancy is direct (unreported) export of groupers caught by live fish transport vessels (LFTVS). As described in footnote 12 of the Johannes & Riepen report, it seems that the LFTVS may either be catching fish directly or receiving transfers from larger 'catcher' vessels at unknown transfer sites, thereby completely bypassing the storage net systems installed at the main 'collection centres' we describe in our article. As our export estimate was based solely on the volume of fish which pass through these collection centres, we have obviously underestimated the total volume of live fish exported from Indonesia by an amount equal to that which exits Indonesia in the above-mentioned fashion.

If we assume that our estimate for the fish which pass through the collection centres is fairly accurate, and furthermore that the estimate given by Johannes and Riepen (1995) for total volume of live food fish exported from Indonesia is also accurate, we must conclude that a substantial volume of live fish (4–7000 t/year) is exported from Indonesia directly, without ever passing through a collection centre. This is particularly alarming, as these fish ostensibly were caught directly by the Hong Kong fleets, and have by all practical purposes been 'stolen' from Indonesia; Indonesian fishermen and their families did not even receive a short-term benefit from the sale of these fish. Furthermore, these fish are 'slipping' out of Indonesia completely unrecorded, making future efforts at control of the trade even more unlikely.

As of November 1966 prices received by fishers in the area had risen significantly, with *Plectropomus* species fetching US$ 12.50–16. These groupers, called *sunu*, are now generally shipped out by air. Between 250 and 500 fish per day were air-shipped in September and October. The less valued *Epinephelus* and *Cephalopholis* species, collectively referred to as *kerapu*, are still shipped out in live fish transport vessels. Fishers and middlemen report that the catch in the region is going down rapidly; after only two years the fish are far fewer and much smaller.

Despite the omission noted above in our export estimates, our basic message in writing this article still holds. While the use of sodium cyanide solution is certainly responsible for 'extensive collateral environmental damage' to reef ecosystems in general, our experience in Eastern Indonesia dictates that the reports in the popular media of 'barren moonscapes' left in the wake of the cyanide fishing boats are exaggerated and untenable. The most alarming issue here, and one which seems to be often overlooked, is the already-realised potential of the live reef food fish trade to completely decimate target fish species' stocks, leading eventually to local or even regional extinction of these species. Continued pressure on the governments of the consuming countries will hopefully avert such a disturbing denouement.

Australia bans exports of wild-caught seahorses

by Marie-Annick Moreau [1]

Seahorses, seadragons and pipefishes are among the most striking fishes in the world, and in Australia they are now among the most protected. In a landmark decision announced on 5 September 1997, the families Syngnathidae (seahorses, seadragons and pipefishes) and Solenostomidae (ghost pipefishes) became the first marine fishes to be officially recognised as wildlife by the Australian Government, as signalled by their removal from Schedule Four of Australia's Wildlife Protection Act (WPA).

A listing on Schedule Four effectively denies species wildlife status by exempting them from the WPA. (Tasmania's spotted handfish is the only other marine fish on the WPA—there by default as an endangered species but never removed from Schedule Four, and thus still technically not wildlife.)

Under the amended legislation, all exports of seahorses, seadragons and pipefishes will require permits as of 1 January 1998; these will only be

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granted for animals derived from approved captive breeding programmes or management plans.

Controls on the exports of seahorses and their kin addresses a major threat to these species: the vast and rapidly increasing international trade for traditional medicines, aquarium fishes and curios. Although dead seahorses make up the largest proportion of sales, trade in live animals is substantial.

Virtually all seahorses destined for aquaria are taken from wild populations. Seahorses are notoriously difficult to keep, and very few survive for long in captivity. Adults require a steady supply of varied live foods, and their vulnerability to a number of fungal, parasitic and bacterial infections means that seahorse tanks must be kept scrupulously clean. Dedicated care by experienced hobbyists is not enough to ensure success: much damage to the seahorse is incurred before the animal reaches the aquarist's tank.

Seahorses are hurt during capture and transport, and are mishandled at every level of the aquarium trade, from the exporters through to the retailers. Starving seahorses is a common practice among holders, given the animals' costly diet of live food. Even public aquaria, with their vast resources and expert staff, concede that these are among the most difficult fishes to maintain in captivity. In a cruel irony for seahorses, their basic unsuitability as aquarium fishes continues to drive the trade: aquarists whose seahorses die commonly go out and buy replacements, thinking that this time, they will get it right.

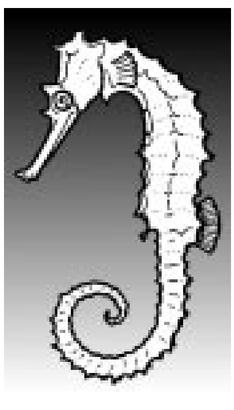
Seahorse numbers appear to be declining markedly in exploited populations throughout Asia. Australian waters harbour one-third to one-quarter of all seahorse species, many of which are heavily fished in other parts of their ranges. As a country with the legislative and legal ability to control seahorse trade, conservationists have envisioned Australia as a potential buffer against the disappearance of the species. The recent legislative reforms raise hopes that Australia is indeed assuming that responsibility.

Australia's move is particularly relevant and timely given the recent local emergence of plans for large-scale seahorse aquaculture. The conservation value of these culturing efforts is highly questionable. Proponents of aquaculture assume that culturing seahorses will enable them to flood the market with captive-bred stock, thus reducing wild harvest. Given the insatiable demand for the animals, this is unlikely to be true. Moreover, similar attempts around the world have had extremely poor success in rearing young, and depend on repeated removal of adults from the wild to maintain their broodstock.

The Australian aquaculture proposals also ignore the threat large-scale farming activity may pose to Asian subsistence fishers, who rely on fishing seahorses for cash income to feed their families; they are presently catching ever smaller seahorses which may become less valuable when set against larger cultured animals. Recent advances do indicate that the technical problems of seahorse husbandry are solvable, but rather than encouraging industrial production in developed countries, the international goal should instead be to establish low-technology seahorse aquaculture in subsistence fishing villages. The development of such alternative livelihoods in developing nations could directly reduce pressure not only on seahorses, but also on a whole range of marine species.

Hopefully , the new restrictions will provide much needed checks and balances on some of Australia's over-ambitious and misguided efforts to culture seahorses.

The Australian decision seems to reflect a growing international commitment to syngnathid conservation. Beginning on 1 June this year, the European Union began monitoring all imports of seahorses. Hong Kong is considering doing the same. Now Australia must administer the controls wisely, undertaking the appropriate research and management initiatives to ensure the long-term viability of these fishes. The precedent has been set: marine fishes can be wildlife too. Let us hope that syngnathids are only the first of many endangered Australian marine fishes to be so recognised.



Management suggestions for the sustainable development of live reef fish food fisheries in the Pacific Islands region

by Dr Andrew J. Smith [1]

There is an increasing awareness within the Pacific Islands region of the potential for negative impacts as a result of uncontrolled or inappropriately managed live reef food fish operations. These impacts have been documented for a number of our South-East Asian neighbour countries, and are beginning to be encountered within this region (see Johannes & Riepen, 1995; and previous issues of this Information Bulletin). The expansion of this fishery into this region is being driven by the increasing demand for live reef fish (LRF)—especially in Hong Kong, Taiwan and southern China—and the diminishing supply of target fish from South-East Asian waters due to over-exploitation and habitat degradation. Having rapidly depleted the target species to a point where commercial fishing is no longer viable in large areas of South-East Asia, the live reef fish operators are now shifting their focus to the reef fish resources of the western and central Pacific.

Despite the problems associated with the uncontrolled LRF fishery, there is the potential for 'adding value' to the region's reef fish resources if the resource is sustainably exploited and exported live to the markets in Hong Kong and Taiwan. However, for this fishery to be sustainably developed, it will require careful and separate management and strict enforcement to alleviate any potential negative impacts.

It appears that in many of the Pacific countries where these LRF operators are established, or attempting to become established, there are rarely management strategies in place to adequately and effectively manage this specific fishery. In addition, most countries do not have the necessary resources, financial or human, to strictly enforce and manage these fisheries.

With these realities in mind, this article attempts to provide some suggestions for managing LRF operations in Pacific Island countries. It is not intended to be comprehensive, and I would certainly welcome any comments, ideas or criticism on the suggestions to assist in making them more relevant to those responsible for fisheries management within the region. Due to the variation in fisheries legislation and regulations within the region, these suggestions will need to be modified as appropriate. They could also be categorised into 'immediate/short-term measures' and 'less-immediate/medium–long-term measures,' but again this would vary from country to country based on capacity to manage and urgency.

The following suggestions are based on the assumption that the fisheries and marine resources agencies in the region want to develop ***long-term, sustainable*** fisheries, that will provide the ***maximum return*** to the respective countries and citizens for the exploitation of their marine resources, while ***minimising environmental impacts***. They primarily focus on the use of licensing agreements as the principal regulatory instrument.

General management suggestions

Pacific Island countries need to recognise the live reef fish food fishery as distinctive, and requiring separate licensing, management and enforcement, from other reef fisheries and especially pelagic fisheries. This will be the only means by which it can be managed and conducted on a sustainable basis and with minimal impacts. The regulatory agencies should, at a minimum (see Johannes & Riepen, 1995, for further details):

- Require a separate licence for fishing for live reef fish, as opposed to combining the licence with other fishing activity licences, or issuing a general fisheries licence;

- Require carefully worded contracts between the fishing company and the governments (national, state/municipal/provincial, local) and the resource owners to ensure environmentally and economically sound operations;

- Develop a catch-and-export monitoring programme; ensure all vessels and their live-fish cargoes are checked for compliance with licence

1. The Nature Conservancy, P.O. Box 1738, Koror, Palau PW 96940. Tel: (680) 488 2017; Fax: (680) 488 4550; E-mail: 103732.3465@compuserve.com

agreements before clearing for Hong Kong or other markets; ensure that catch-effort and purchasing logs are maintained by the company and submitted regularly to the relevant government agency;

- Ban any transshipment of live reef fish at sea; require all live fish transport vessels to clear from a recognised port (where monitoring can occur) before leaving for Hong Kong; or where live fish exports are permitted by air they should only be from designated airports;

- Establish an effective observer programme, or expand the current pelagic fishery observer programmes to include LRF operations. Government agencies should aim to have observers present on all fishing trips and have access to all other related operations of the LRF companies. The observers should monitor compliance with the licence agreements. The cost of the observers while on the vessels should be borne by the fishing companies;

- Place spawning aggregation sites of target species off limits to commercial fishing, or close commercial grouper fishing entirely during the spawning season;

- Ban the possession, use, storage and/or transportation of any explosives, noxious substances (including sodium cyanide) for the purpose of killing, stunning, disabling or taking fish or in any way rendering fish more easily taken, on all fishing boats, fish transport vessels and LRF operators' facilities; [2]

- Ban the possession, use, storage and/or transportation of compressed air equipment (e.g. SCUBA or hookah) on live reef fish fishing boats and fish transport vessels;

- Provide advice and awareness materials to local fishermen/communities concerning the problems associated with live reef fishing and how to minimise them, using actual examples of problems experienced elsewhere;

- Provide advice to any resource owner or local businessman who wishes to enter into a formal agreement with a live reef fish export company, including basic economic and marketing data on the LRF trade, to ensure they have strong negotiating positions when dealing with foreign operators;

- Ban the export of fingerlings of live reef fish, and place size limits on adult target fish species;

- Place an export ban on wild-caught *Cheilinus undulatus* (humphead wrasse/ Napoleonfish/ Maori wrasse) and *Cromileptes altivelis* (Barramundi cod/ pantherfish/ polkadot grouper). These two species are the prime targets for the live reef fish trade and are the first to be overfished. They are also species about whose biology and life history little is known. Until stock assessments are initiated and completed for these species within any designated fishing areas, it is strongly recommended that their harvest be permitted only in the subsistence and artisanal fisheries and only for the domestic market;

- It is recommended that an Environmental Impact Assessment (EIA) be prepared for each live reef fish export operation. The costs of preparing the EIA should be borne by the LRF operator.

Most countries require foreign and/or new businesses to submit an application for relevant business, foreign investment and/or fishing permits. Where such requirements exist, I would strongly suggest that as much detail as possible on any proposed LRF operation be requested from the applicant at this early stage. At a minimum, the proponent should provide the following information in the form of an operational plan:

- a detailed description of the proposed operation;

- ownership, control and management of the operation/company;

- target species;

- where the fishing and fish buying are to occur;

- how fishermen will be hired and/or used;

- a summary of the negotiations for access to any fishing area with the customary owners/stewards/controllers and any agreements and terms reached;

- the specific methods, equipment and treatments (e.g. antibiotics) to be used;

- infrastructure requirements (existing and proposed);

2. Some operators use antibiotics and/or anesthetics to treat fish prior to shipping/transporting. If this is the case, the specific chemicals and usage should be documented and strictly controlled.

- human resource requirements (clearly identifying where foreign or non-citizens will be required, what they will be doing, and for how long);
- training components (a detailed plan);
- record keeping (what records will be kept and how; minimum requirements should be set by the management agency);
- fish storage, processing and transportation mechanisms;
- proposed marketing;
- operational budget;
- any other items deemed necessary (e.g. an EIA).

Suggested minimum conditions for Live Reef Fish Fishing Licence Agreements

The minimum conditions that should be considered for inclusion in any Live Reef Fish Fishing Licence Agreement are summarised below. Each country's regulatory agencies concerned with issuing licences will need to assess these in terms of their existing laws and regulations. Where necessary, modifications to current legislation or the introduction of new legislation may be required for this fishery. In general, these suggestions are based on a form of limited entry/access fishery, to be implemented through issuing annual conditional licences for fishing/fish buying in specific areas only. They are also directed at encouraging the greatest level of local participation in the fishery and thereby gaining the maximum return of benefits to the reef owners/stewards.

Licence conditions for live reef fish operators should encompass, but not be restricted to, at least the following:

- Licences should be issued for specific locations or areas for a maximum of one year, renewable upon review. For the live reef fish export fisheries, it is recommended that only one operator per designated area be permitted until more is known about this fishery and its impacts. Short licence periods and area restrictions are necessary due to the real potential for rapid over-exploitation of the target species;
- Where appropriate, customary tenure, use rights and compensation issues need to be resolved prior to issuing a licence designating or authorising an area for commercial live reef fish operations. The responsibility for resolving these issues should primarily be the licence applicant. The applicant must produce a signed agreement with the recognised customary owners/stewards in which the terms of access and usage are explicitly set out. Any terms of the agreement must not conflict with national, state/municipal/provincial laws and policies. This agreement must be endorsed by the relevant state/municipal/provincial authorities, and confirmed or authenticated by officers of the relevant regulatory agency (or preferably signed in the presence of the officer) prior to the issuing of a licence;
- It is preferable that licences be issued to national/local enterprises, rather than foreign companies, to ensure maximum involvement and return of benefits to the country;
- Where foreign vessels are used in joint-venture operations, the foreign crew numbers should be limited to the minimum required to operate the vessel and maintain the fish. This will discourage the use of foreign crews in fishing operations, while encouraging the participation of local fishermen. Most local fishermen fishing their own reefs tend to have a vested interest in ensuring that fishing is sustainable and impacts minimised;
- Foreigners or non-citizens should not be involved in the actual capturing of live fish products, except for the purposes of training (a time limit should be placed upon training, e.g. three to six months—shorter times are preferable);
- For live reef fish operations, company transport vessels should be limited to carrying the fish only and not be permitted to conduct fishing operations. Fish should be purchased from local fishermen once training has been completed. Such vessels operating in remoter areas should also be required to have facilities for storing iced/chilled fish and to purchase any commercially acceptable by-catch fish[3] for sale in urban centres. Fish should not be delivered or transshipped to another vessel without prior written permission;

3. Johannes and Riepen (1995: 23–24) reported that in two studies of hook-and-line LRF operations in PNG, only 10 per cent of the catch consisted of target species. The LRF operators refused to purchase the by-catch or dead fish (even of the target species) and so the fishermen were left with fish they couldn't sell and more than their families could consume. Requiring LRF operators to purchase by-catch in such situations will reduce wastage and provide additional benefits to the fishermen.

- In some circumstances, it may be appropriate to limit the size and number of LRF transport vessels and holding pens/facilities. This is to reduce the potential for companies to extract as many target species as possible as quickly as possible—i.e. to encourage longer-term sustainable operations;

- The licencee must permit a fisheries officer or official observer to board the vessel and must provide accommodation to such observers free of charge at any time while the vessel is operating under the licence;

- Live fish exports should only be permitted from designated ports or airports to facilitate inspection and monitoring of the species and volumes being exported;

- The use, storage and/or transportation of scuba or hookah equipment should not be permitted. With this fishery, the use of hookah is usually associated with the use of sodium cyanide or with fish traps—the former must be banned and the latter should be discouraged due to the damage to corals (often used to anchor the traps) and the damage to the fish (abrasions from the trap resulting in lower-quality fish);

- The use, storage and/or transportation of any explosives, noxious substances (including sodium cyanide) for the purpose of killing, stunning, disabling or taking fish or in any way rendering fish more easily taken, should not be permitted;

- Licencees must maintain detailed daily records of their catches or purchases, ideally including: time and location caught; species; number and weight of each species caught; capture method; price paid to the fishermen (include name and contact details of fishermen); mortality rates for each live fish species (at each stage of the operation); sale price received; export records, including copies of the shipment manifests and invoices; and any other data or information required by the regulatory agency for management purposes.[4] These records should be submitted to the regulatory agency monthly. All data submitted must be treated with strict confidentiality by the regulatory agency, and should be analysed promptly. The burden of proof for reporting must be on the operator. Local fishermen should be trained by the licencee to maintain basic catch records, and the recording of catch data made a prerequisite for purchasing fish from the fishermen;

- The vessel, its owners, operators and crew must ensure the protection of coral reefs from damage or degradation at all times during the fishing and vessel's operations (including anchoring). Destroying or damaging coral reefs, either directly or indirectly, deliberately or through negligence should result in prosecution and/or suspension of the licence. This also applies to using coral pieces to anchor traps, if used;

- Fees for access to the resources should be included. As a limited-entry fishery is proposed, there is a degree of 'exclusivity' involved and it would be appropriate to require fees to be included as a licence condition. The mechanism of calculating fees and how the fees are used/distributed would need careful consideration (see discussion later concerning monitoring costs). If a number of companies are vying for licences, then a competitive bidding process may be appropriate;

- Other conditions normally applied to fishing vessels operating in the fisheries waters of the country.

Other management issues

Local empowerment

For management of the fisheries to be effectively enforced, especially in the remoter areas where many of the LRF operations occur, it will often be necessary to rely on local enforcement, including traditional resource owners/stewards. Therefore any management strategy or plans should utilise the traditional mechanisms of marine tenure and resource control wherever feasible and practical. This should include mechanisms for reporting licence and/or access agreement infringements to the relevant fisheries officers. For this to be effective the traditional reef owners/stewards will need to be made fully aware of the conditions attached to the licences and the reasons for those conditions. In addition, there will need to be a system of checks and balances that ensure that the system is functioning effectively and those with vested interests are not attempting to manage themselves. This

4. Such detailed data are required because to date very little information is available on this fishery and the target species. Therefore there are few historical data to assist managers in regulating the fishery. This level of data will help managers to identify problems within the fishery, such as falling catch per unit of effort, over-exploitation, etc. It will also provide data on the survival rates of the fish and the actual value of the fishery to the community and country—information valuable in assessing new LRF applications or LRF licence renewals.

could be partially achieved through spot checks by fisheries officers.

Limited entry/access fishery

Management through using the licensing conditions noted above (i.e. annual licences and requirements for access agreements with traditional reef owners/stewards) is effectively establishing a form of limited entry/access fishery. If such an approach is used, then local authorities and reef owners/stewards must be made aware and understand that this will reinforce their control over outside fisheries operations using their reefs. Additionally, where appropriate (e.g. remote areas), such access agreements should consider requiring outside operators to provide relevant aid services or infrastructure for the support and development of the local fisheries.

Closed seasons and/or areas

Local knowledge of fish aggregation sites should be used to identify areas and seasons where commercial fishing should not be permitted. Past experience in Palau and elsewhere has shown that it is possible to decimate reef fish stocks at aggregation sites in relatively short periods of time. Closed seasons and or areas will, however, only be effective if they can be enforced; this issue must therefore be resolved before imposing any closures or restrictions.

Catch quotas

At the current time, not enough is known about the biology or stock sizes of the target species for catch quotas to be used.

Costs, fees and fines

The costs of local monitoring and enforcement need to be taken into consideration. It will be important that where appropriate, the fishing company should cover the costs involved in directly monitoring its operations. Consideration should be given to promulgating regulations that a certain percentage of any fines levied on an operation go back to the community that assisted by reporting the infringement; it is important that communities be aware that the reporting of live reef fish operators' illegal activities will result in a portion of the fine coming back to their community. This will be essential for effective monitoring and enforcement of operations in remoter areas.

Monitoring activities

The commercial live reef fish fisheries can only be managed effectively if the necessary data and information are collected, analysed and acted on. Suggested actions for effective monitoring of this fisheries sector include:

- The appointment of an officer at the national level to be responsible for overseeing the monitoring of catches, data collection, preparing reports and liaising with the licensing officers and with the relevant state/municipal/provincial and community authorities;

- A data collection system and database should be established by the relevant agency to collect, analyse and report the data from the fishery. Appropriate data collection forms or log books should be prepared for the commercial live reef fish fisheries and mechanisms for their distribution and collection established;

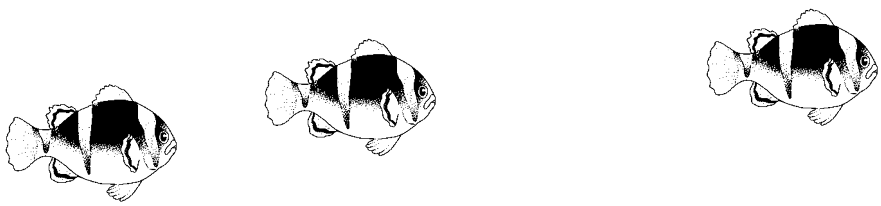
- National patrol boats should be enlisted to become more involved with the monitoring and enforcement of commercial live reef fish export operations, in addition to their more usual role of oceanic fisheries enforcement. This would be particularly relevant with the live reef fish operations that involve larger carrier vessels operating in remote locations.

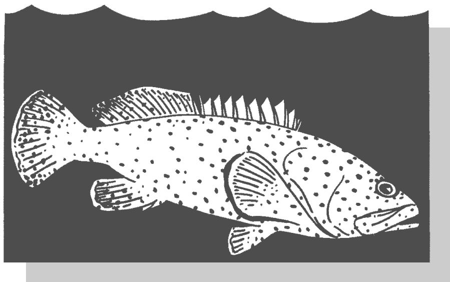
Costs of monitoring and data analysis

The costs of monitoring and managing the commercial live reef fish fishery need to be shared with the industry. The imposition of a management fee, in addition to the licence fee, should be considered.

Reference

JOHANNES, R.E. & M. RIEPEN. (1995). Environmental, economic, and social implications of the Live Reef Fish trade in Asia and the Western Pacific. Forum Fisheries Agency, Honiara and The Nature Conservancy, Honolulu. 81 p.





noteworthy publications

live reef fish

RIMMER, M.A. & B FRANKLIN. (1997). Development of Live Fish Transport Techniques. FRDC Projects 93/184 and 93/185. DPI (Department of Primary Industries), Cairns, Queensland, 4870 Australia. 151 p.

This report is an outcome of a three-year study on the development of live fish transport techniques. The report deals with various experiments carried out with tropical and temperate finfish species in far northern Queensland and in Tasmania, as well as some general guides to fish handling and system design.

Copies can be obtained from AUSEAS in Brisbane, Queensland; for details see the AUSEAS Publications Page. http://www.dpi.qld.gov.au (Note: AUSEAS also sells some other live seafood related reports—see the above web site for details).

Summary

The live fish trade is a rapidly expanding component of Australia's commercial fishing and aquaculture industries. Exports of live Australian finfish have increased steadily over the last five years and in 1994–95 were estimated to be worth AU$ 9 million. Marketing of live reef fish finfish is regarded as a value-adding procedure because live fish obtain substantially higher prices than fresh-chilled or frozen product.

This report provides details of various aspects of live fish transport in these three main areas:

1. Capture and pre-transport maintenance,

2. Packaging and live transport,

3. Post-transport maintenance.

The capture and pre-transport maintenance of live fish requires some modification of techniques traditionally used by commercial fishers and processors. Detailed information is provided on capture and handling techniques, construction and maintenance of live-fish-holding facilities, and design and operation of recirculating filtration systems.

Barotrauma is an important cause of mortality amongst line-caught finfish destined for live fish markets. Coral trout (*Plectropomus leopardus*) and blue throat wrasse (*Notolabrus teiricus*) with severe barotrauma had a consistently higher mortality rate than fish with moderate or mild barotrauma. Coral trout captured in shallow water (0–9 m) exhibited lower mortality than those captured from deeper water (10–19 and 20–29 m). Blue-throat wrasse captured in depths <20m exhibited very low mortality after capture, whereas wrasse captured at 20–35 m exhibited substantially higher mortality. Swim-bladder puncture only slightly improved survival in coral trout, providing an overall decrease in mortality of about 10–20 per cent and swim-bladder puncture in blue-throat wrasse had no discernible effect on survival.

Four types of restraining material were assessed with regard to their use in coffs (fish holding cages): salmon net (knotless) mesh; trawl mesh; plastic oyster mesh; and chicken wire. The coff design that resulted in the least overall damage to fish was salmon mesh, closely followed by the plastic mesh material. Damage levels and mortality rates were higher for coffs constructed with trawl mesh and chicken wire. The economic implications of the use of the various restraining materials is discussed. Based on the results of this experiment, an improved coff design, incorporating a bag made from knotless salmon net cage material and external frame, was developed to improve survival and fish health during the initial holding phase.

There are basically three methods that are commonly used in Australia for transporting live fin-fish by air:

1. the polystyrene seafood box,
2. the 'pickle barrel' system,
3. the 'big box' system.

Details of these various packaging techniques are provided. 'Purging' fish prior to packing to alleviate water quality degradation during transport is necessary for only 2–3 days.

The major water-quality effects experienced by fish during transport are: low dissolved oxygen levels due to oxygen consumption by respiration; accumulation of carbon dioxide from respiration; depression of pH caused by carbon dioxide. Time-series experiments showed that most water-quality degradation occurs rapidly during the first hour after packing. An experiment to test the effects of containment of fish demonstrated that containment *per se* had no effect on survival, indicating that mortality can be attributed to the changes in water quality that occur during fish transport in closed systems. A manipulative experiment testing various water-quality variables indicated that carbon dioxide accumulation is the major limiting factor affecting survival of fish during live transport. High carbon dioxide levels cause hypercapnia, and narcotise and eventually kill the fish.

Although reducing the water:fish ratio improves the economics of live fish transport, it also aggravates the problems of water-quality degradation in the transport medium. The physiological responses of seawater-adapted barramundi (*Lates calcarifer*) were studied during simulated live transport and transport under circumstances of elevated carbon dioxide or ammonia. Analysis of blood samples from the fish showed that simulated transport caused the plasma pH of the fish to fall, threatening the blood's ability to transport oxygen, but the red blood cells apparently defended their internal pH and oxygen transport capacity, and swelled measurably as a result. Exposing fish to unusually high carbon dioxide or ammonia levels caused plasma pH to fall to near lethal levels. The effects of both of these wastes need to be considered when studying the responses of fish to live transport.

The use of temperature reduction was evaluated as a method for reducing mortality in live fish transport applications by reducing fish metabolism. Barramundi and banded morwong (*Cheilodactylus spectabilis*) were subjected to slow and rapid cooling regimes of 5° and 8° or 10°C below ambient temperature, and then subjected to transport trials. Most temperature reduction treatments improved water quality significantly. Best survival (89%) of barrmundi was achieved by reducing water temperature by 10°C at the slow cooling rate, while for banded morwong, all temperature reduction treatments significantly improved survival.

The use of sodalime to reduce carbon dioxide accumulation in live fish transport applications was evaluated. Prototype live fish transport systems using sodalime were effective in reducing carbon dioxide levels and increasing pH in the transport medium. The prototype systems dramatically increased survival from 31 to 100 per cent for barramundi and from 39 to 90 per cent for banded morwong. Requirements for continued commercial development for these prototype systems are discussed.

Road transport of live fish is a well established industry in the US and most of the techniques used are readily applicable to Australian conditions with minimal modification. The information in this report was obtained from published sources and from conversations with commercial road transport operators in Arkansas, Texas and Louisiana. Some of the salient points discussed are:

- matching truck size and design to specific needs,
- use of insulated tanks,
- transporting fish in dark or low light conditions,

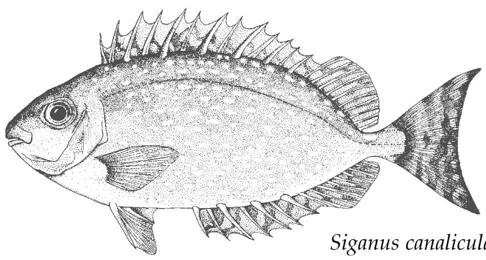
- design of tanks and loading systems to minimise fish handling,
- provision of oxygen to compensate for oxygen consumed by respiration,
- provision of water agitators to off-gas carbon dioxide,
- use of liquid oxygen instead of gaseous oxygen,
- provision of adequate amounts of oxygen during the loading procedure, when oxygen consumption is highest,
- reduction of water temperature to reduce the metabolic rate of the fish during transport,
- extensive pre-transport 'tempering' to adapt the fish to transport conditions,
- effects of temperature and fish size on loading rates, and
- recommended loading rates for US finfish species.

Using the procedures and equipment described in this report, live fish transport operators in the US haul fish from the southern central US to markets on the east and west coasts, as far south as the Mexican border, and north into northern Canada. These trips can be up to five days in duration. Since the area covered by these operators exceeds the area of Australia, adoption of these procedures and equipment should enable successful road transport of live fish throughout Australia.

The health of transported fish was evaluated with respect to both fish health (bacterial and ectoparasite levels) and levels of potential human health pathogens (Salmonellae and *Vibrio parahaemolyticus*) for barramundi and banded morwong. Bacterial levels were low for both species immediately following transport, and one week after transport. All samples were well within the required criteria for human consumption. Numbers of ectoparasites varied depending on the source of the fish, but in all cases were insufficient to cause any fish health problems during the post-transport holding period.

KIM, S.J. & S.D. CASE. (1996). Analysis of laws addressing destructive fishing practices in the Asia/Pacific Region (Sodium cyanide/Live reef fish trade). The Nature Conservancy Asia/Pacific Program. 118 p.

This analysis is intended to serve as a resource for use by any legislator, legislative analyst, policy maker or other individual seeking to bolster the law of his or her country to address this threat. It outlines relevant laws in 29 different countries in the Asia/Pacific region, including 16 Pacific Island countries. It then discusses provisions that, taken as a whole, offer strong legislation to curb these destructive fishing practices.



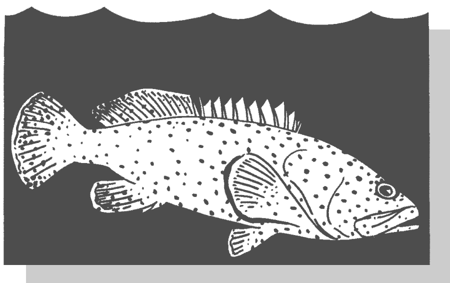
Siganus canaliculatus

BARBER C.V. & V.R. PRATT. (1997). Sullied Seas: Strategies for combating cyanide-fishing in Southeast Asia and beyond. World Resources Institute and International Marinelife Alliance–Philippines, September 1997.

This is a well-illustrated professionally produced volume full of information on, and advice for the management of the live reef fish trade (both aquarium and food fish). The contents are summarised in this issue of the Live Reef Fish Information Bulletin on page 26. A Chinese (Mandarin) translation should also be available soon.

For information on how to obtain a copy, contact:

The International Marinelife Alliance–Philippines
36 Santa Catalina Street, Barangay Kapitolyo
Pasig City, Metro Manila, The Philippines
Tel: (63-2) 633-5687
Fax: (63-2) 631-9251
Email: imaphil@mnl.sequel.net



late news
live reef fish

Chinese investors to export live fish from Kiribati

The Kiribati Foreign Investment Commission has given approval to two Chinese investors to begin a Live Fish Export investment in Kiribati on a one-year-trial basis. Senior Foreign Investment Officer Tiiroa Rooneti says the company will collect live reef fish and lobsters for export to its own markets, Radio Kiribati reports. Rooneti says the investors have shown they will use an initial capital of AU$ 2 million (US$ 1.4 million).

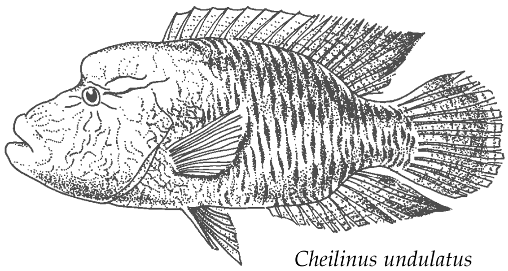
Source: TARAWA (PacNews)

Restaurant in Chinatown, Sydney selling live Napoleon wrasse

Mr Michael Aw of the conservation group, OceanNEnvironment, reports: 'Restaurants in Chinatown, Sydney, are selling live Napoleon wrasse. An 80 cm Napoleon was seen squashed into a small tank at the Golden Century Restaurant, Sussex Street, Haymarket on Wednesday 29 Oct ober 1997. The price tag was AU$ 1,000. OceanNEnvironment is now gathering resources to purchase this fish for release in Queensland waters.'

Editor's comment:

> Combine such extravagant domestic prices with the high prices received by Australian exporters of Napoleon (humphead) wrasse to Asia and we have an explosive potential for overfishing of this species in Australia. It can be fished sustainably, *in principle*. But, given the emergence of these strong new incentives to catch as many as possible, we hope the authorities are hard at work ensuring that it is still being, and will continue to be, fished sustainably *in practice*..



Cheilinus undulatus

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 South Pacific Commission (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). Funding is provided by the Canadian International Development Agency (CIDA) and the Government of France. 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