



Cyanide fishing on Indonesian coral reefs for the live food fish market – What is the problem?

Peter J. Mous¹, Lida Pet-Soede², Mark Erdmann³, Herman S.J. Cesar⁴, Yvonne Sadovy⁵ & Jos S. Pet⁶

Abstract

According to three precautionary estimations, the reef-degrading capacity of the cyanide fishery for food fish on Indonesia's coral reefs amounts to a loss of live coral cover of 0.047, 0.052 and 0.060 m² per 100 m² of reef per year. These estimates for the rate of coral cover loss are low compared to published rates of natural coral recovery. Differences in growth rate between species of hard coral will cause coral reefs to take longer to recover from the effects of cyanide fishing than a direct comparison of the rate of coral cover loss with published rates of natural coral recovery would suggest. Still, the cyanide fishery for food fish may not be as threatening to Indonesia's coral reefs as is sometimes assumed, especially not as compared to other threats such as blast fishing (responsible for a loss of live coral cover amounting to 3.75 m² per 100 m² of reef per year, (Pet-Soede, Cesar & Pet, 1999)), or coral bleaching caused by global climate change (cf. Hoegh-Guldberg, 1999). Setting the input variables for the estimates at extreme values did not change these conclusions substantively. The depletion of grouper stocks by the trade in live reef food fish, however, is worrying from both fisheries and conservation perspectives. Strategies to abate the depletion of these grouper stocks should not only consider cyanide fishing, but also other fishing methods.

1. Introduction

The Live Reef Food Fish Trade (LRFFT) has rapidly expanded throughout Southeast Asia and beyond during the 1990s, and the demand for live fish is projected to grow even more in the future (Dragon Search, 1996). The trade concentrates on the catch of groupers (Serranidae, especially *Cromileptes altivelis* and species of *Plectropomus* and *Epinephelus*) and Napoleon wrasse (*Cheilinus undulatus*), catering to 'high-end' customers who are willing to pay up to hundreds of dollars (US\$) per serving (Johannes & Riepen, 1995). These fish are top predators, sedentary in character and strongly territorial; they are typically long-lived and slow growing; many assemble in large numbers to spawn. These characteristics contribute to the rampant overexploitation engendered by the LRFFT, which has already led to calls to include many of the target species in Appendix II or III of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) (Lau & Parry-Jones, 1999). Two of the target species (*Cheilinus undulatus* and the giant grouper

Epinephelus lanceolatus) are currently listed as 'vulnerable' on the International Union for the Conservation of Nature (IUCN) Red List (Baillie & Groombridge, 1996).

Besides the problem of overexploitation of target species, there is a concern that one of the most widely used capture methods, the application of cyanide solution to stun the fish, is causing severe reef degradation (Johannes & Riepen, 1995). The perceived problem of reef degradation, together with the intriguing nature of the trade has attracted public attention, put pressure on policy makers to abate cyanide fishing, and created a greater willingness among environmental organisations to get involved in the LRFFT issue (Johannes & Riepen, 1995; Pratt, 1995; Barber & Pratt, 1997a; 1997b). However, there is still considerable uncertainty about the extent of the coral reef degradation by cyanide fishing for live food fish. Laboratory experiments showed that exposure of zooxanthellate hard coral to a range of cyanide doses likely to occur during cyanide fishing results in coral bleaching or death of the polyps (Jones & Steven,

1. The Nature Conservancy Coastal & Marine Program, Indonesia. Email: pmous@attglobal.net
2. Fisheries Management Consultant. E-mail: lidapet@attglobal.net
3. University of California, Berkeley & Indonesian Institute of Sciences. E-mail: flotsam@manado.wasantara.net.id
4. Institute of Environmental Studies, Free University Amsterdam & Environmental Economics Consulting (CEEC). E-mail: herman.cesar@ivm.vu.nl
5. The Department of Ecology and Biodiversity, The University of Hong Kong, Hong Kong, People's Republic of China. E-mail: yjsadovy@hkusua.hku.hk
6. The Nature Conservancy Coastal & Marine Program, Indonesia. E-mail: jpet@attglobal.net

1997). Bleaching of corals is caused by cyanide affecting the photosynthesis of the symbiotic zooxanthellae (Jones & Hoegh-Guldberg, 1999; Jones, Kildea & Hoegh-Guldberg, 1999). However, the toxicity of cyanide to corals under experimental conditions is, in itself, no proof for degradation on the scale of a reef. This is because the rate of coral loss due to cyanide fishing may be lower than the rate of natural coral growth, or it may be that under natural conditions cyanide is dissipated too rapidly by water currents to affect exposed corals (cf. Jones & Steven, 1997).

It is also unclear how reef degradation from the cyanide fishery for live food fish compares to the problem of overexploitation of target fish and to the problem of reef degradation caused by other destructive fishing techniques. Erdmann & Pet-Soede (1996, 1999) and others have previously suggested that the reef degradation from cyanide fishing may be wrongly emphasised, and that the more important issue requiring attention in the LRFFT is the potential for overexploitation of the target species (irrespective of capture technique). McManus, Reyes & Nanola (1997) have concurred that reef degradation from cyanide fishing in the LRFFT certainly is minimal compared to that wrought by blast fishing. Unfortunately, quantitative figures are generally lacking to help clarify this debate. One exception is the model of the effects of destructive fishing methods on coral cover in Bolinao (Philippines), which gives an estimate of a decrease of only 0.4% live coral cover per year due to destruction by cyanide fishing for ornamental fishes (McManus, Reyes & Nanola, 1997).

In an attempt to further clarify this debate and thereby better focus attention on the LRFFT issues most worthy of action, we have quantitatively estimated the reef degradation potential of cyanide fishing in the LRFFT in Indonesia by three independent methods, using both data from published reports and the authors' collated experience with cyanide fishing. We hope that this opinion paper will stimulate additional information inputs that are needed to make decisions on how reef conservation dollars may best be directed.

2. Calculation of the effects of cyanide fishing on coral reefs

One way to assess the degradation afflicted by the LRFFT is to estimate what amount of reef is being destroyed per fish caught with cyanide, and multiply this by an estimate of the number of fish caught by the cyanide fishery. Even though this method requires the input of imprecise variables, this method should provide a crude approximation of the order of magnitude of reef degradation caused by cyanide fishing in the LRFFT.

In the Spermonde Archipelago (Central Indonesia), on average one bottle (0.5–1 L) of cyanide solution is used to catch one fish (Pet & Pet-Soede, 1999). We assumed this fully destroys live coral cover in an area of one square metre, both by poisoning the coral polyps and by the fisher breaking away coral to extract the stunned fish.

Based on personal observations, this figure of one square metre is probably an over-estimation for reefs with a relatively high cover of massive coral structures, as retrieving stunned fish that hide in the cavities under these massive structures will not require nearly as much breakage as retrieving fish that hide between branching corals. Additionally, squirted fish often flee their shelters, thus the damage to coral by the diver retrieving the fish is minimised (pers. observ.). Even the chemical damage per fish caught may be limited to an area smaller than one square metre (pers. observ.; Erdmann & Pet-Soede, 1996). Finally, this figure may result in an over-estimation of the reef-degrading capacity of the LRFFT because we assumed that the 'killing area' was fully covered with live coral.

However, we decided to use the one-square-metre figure because we felt that the consequences for management of under-estimating the reef-degrading capacity of the LRFFT, i.e. allowing the cyanide fishery to continue, would be more severe than consequences of over-estimation, i.e. directing too many resources to the abatement of the cyanide fishery (precautionary approach).

The estimate of reef area destroyed per fish caught, using Indonesia as an example, was multiplied by the number of fish caught per km² per year, which was derived from:

1. the potential production and yield of grouper on pristine coral reefs where exploitation has only just begun, usually by large-scale operations (Pet & Pet-Soede, 1999);
2. the mean observed effort of cyanide fishers times the estimated catch per unit of effort (CPUE) in situations where reefs have already been exploited for some time, and where the most fish are caught by medium-scale operations (Pet & Pet-Soede, 1999);
3. the volume of the LRFFT in Hong Kong, a significant proportion of which comes from Indonesia. In Indonesia live food fish is also caught by other methods, mainly hook-and-line and bamboo traps (pers. observ.; Erdmann & Pet-Soede 1999), but we adopted a precautionary approach by assuming that all fish were caught with cyanide.

2.1 Method I: Estimation based on the potential production and yield of groupers

Estimates for the Maximum Sustainable Yield (MSY) of groupers in other coral reefs average 1000 kg per km² coral reef per year (Russ 1991; Jennings & Polunin 1995). If a pristine reef were to be exploited at a rate higher than this MSY, this would eventually lead to lower catch rates. We assumed an exploitation rate for the first year of twice the MSY, i.e. 2000 kg per km² per year, because the LRFFT tends to over-exploit its fishing grounds (Bentley, 1999). The average individual size of fish caught by large-scale cyanide fishing operations in relatively pristine areas has been estimated at 3.33 kg (Pet & Pet-Soede, 1999), about 2 kg heavier than the overall average size of fish encountered in the LRFFT (Johannes & Riepen, 1995). Hence, the total catch amounts to 600 fish per km² reef area, resulting in an estimated loss in coral cover of 0.060 m² per 100 m² of reef per year.

2.2 Method II: Estimation based on fishing effort and CPUE

In Komodo National Park, a creel survey was conducted in 1997 to describe patterns in resource use. During this survey, which covered the full surface area of the Park and which was repeated 18 times during the 12-month period, the number of fishing operations using hookah compressors was recorded. Most, if not all, of the hookah compressor operations in the Komodo area use cyanide to catch live fish (pers. observ.). The crew, usually consisting of c. five persons of whom two were hookah divers, operated from a motorised boat making trips of three days each. At that time, the ban on cyanide fishing was not enforced, mainly because it was usually impossible to obtain legal proof that cyanide was actually used. The number of cyanide operations in the Park seemed high compared to areas outside Park boundaries, probably because fishing opportunities within Park boundaries were still good. Within the boundaries of the Park, on average 3.2 medium-scale cyanide operations per day were encountered (Pet, 1999). The coral reef area in the Park, estimated as a 50-m wide strip following the perimeter of all islands including their shallow reef areas, was c. 17 km². Therefore, the daily effort per km² of coral reef averaged 0.19 operations.

Estimates for the catch per trip in Komodo were not available. Therefore a catch estimate was used from the Spermonde Archipelago, an area approximately 400 km from Komodo. In Spermonde, an operation of similar size uses about 7.5 bottles of cyanide to catch an equal number of fish during each of the two days that fishing actually takes place (Pet & Pet-Soede, 1999). Therefore, the total

area potentially destroyed was 7.5 fish times 0.19 operations times 365 days times one m², i.e. 520 m² per km² reef area. Assuming that the targeted reef patches were fully covered with live coral, it follows that the rate of live-coral-cover loss amounts to 0.052 m² per 100 m² of reef per year.

2.3 Method III: Estimation based on the volume of the trade in live reef food fish

The annual imports of live reef fish into Hong Kong amounted to c. 32,000 tonnes in 1997. It is believed that Hong Kong accounts for c. 60 per cent of the total LRFFT volume, and that 50 per cent of all live reef fish originates from Indonesia (Johannes & Riepen, 1995; Lau & Parry-Jones, 1999). Hence, the total amount of fish from Indonesia that reached their destination must have amounted to 27,000 tonnes. This estimate is high (see appendix), but we used it purposefully to ensure we did not underestimate the capacity of the live reef fish trade to damage the reef. Assuming that 50 per cent of all fish caught dies shortly after catching or during transport (Johannes & Riepen, 1995; Indrawan, 1999), the annual catch from Indonesia's coral reefs (85,707 km², Tomascik *et al.*, 1997) amounts to 54,000 tonnes, or 630 kg per km² per year. Assuming that most fish caught originated from medium-scale operations, the average body weight of the fish in the landings was 1.33 kg (Pet & Pet-Soede, 1999). It follows that the associated rate of live-coral-cover loss would be 0.047 m² per 100 m² of reef per year.

2.4 Sensitivity analysis

To assess to what extent the methods presented above may be under- or over-estimating the actual reef degradation by the cyanide fishery, we did the same calculations with each of the variables set at what we considered extreme values (Table 1). It should be noted that the minimum and maximum estimates relate to averages over a year, for all over Indonesia, which is why our lower and higher extreme values, which we named 'conservative' and 'worst' (Table 1), may appear not so extreme to some readers. For example, there are reports of whole shipments of live fish dying, but it would not be correct to use this record as a lower estimate for post-harvest mortality in our calculations, because there will also be shipments with little mortality. Also, the resulting lower and maximal estimates for reef degradation are extremes in a sense that we think it is unlikely that all variables are either on the 'conservative' side, or on the 'worst-case' side. However, the extreme estimates can be interpreted as a means to assess the risk of drawing the wrong management conclusions.

The conservative estimates for loss of coral cover caused by the LRFFT ranged between 0.004 and 0.005 m² per 100 m² of reef per year, whereas the worst-case estimates ranged between 0.5 and 0.7 m² per 100 m² of reef per year.

3. Conclusions & discussion

The estimates for loss in live coral cover caused by the cyanide fishery for food fish in Indonesia ranged between 0.05 and 0.06 m² per 100 m² of reef per year. Though the values for the various variables used in each of the three methods are only approximate, all

methods arrived at a level of reef degradation that was of the same order of magnitude.

These estimates for reef degradation are low, both considered by themselves and as compared to reported values for reef recovery. The conservative estimate suggests a negligible amount of reef degradation caused by the LRFFT: after a century of cyanide fishing at its present level of effort, only 0.4 m² per 100 m² of live coral cover would be lost. Even according to the worst-case estimates, it would still take the LRFFT about 40 years to decrease live coral cover by 25 m² per 100 m² of

Table 1. Results of the sensitivity analysis for the estimation of reef degradation, expressed as the yearly loss of live coral cover in m² per 100 m² of reef, caused by the Live Reef Food Fish Trade (LRFFT). For each input variable, a range of likely values was estimated by the authors. 'Best': Best precautionary estimate (equals the arithmetic or geometric mean of the extremes of the range). 'Conservative': Extreme of the range that leads to more conservative estimates for reef degradation. 'Worst case': Extreme of the range that leads to higher estimates for reef degradation.

Method / variable	Best	Extremes	
		Conservative	Worst case
Area of live coral cover lost per cyanide bottle used or per fish caught(m ²)	1.0	0.3	3.0
Method I: Potential production and yield of groupers in pristine areas exploited by large-scale operations			
MSY (kg . km ² coral reef . yr ⁻¹)	1,000	500	2,000
Body weight per fish (kg) *	3.33	6.66	1.67
Reef degradation **	0.060	0.005	0.719
Method II: Fishing effort and CPUE of medium-scale operations			
Effort (trips day ⁻¹ . km ² reef)	0.190	0.095	0.380
Fish caught per unit of effort	7.50	3.75	15.00
Reef degradation **	0.052	0.004	0.624
Method III: Volume of LRF, mostly caught by medium-scale operations			
Hong Kong imports (tonnes)	32,000	25,600	38,400
Through Hong Kong (%)	60	80	40
From Indonesia (%)	50	70	30
Post-harvest mortality (%)	50	30	70
Body weight of fish (kg) *	1.33	2.66	0.67
Reef degradation **	0.047	0.004	0.502

* The average body weight for fish caught was set at a higher value in Method I than in Method III, because large-scale operations operating in pristine areas tend to catch larger fish than medium-scale operations that tend to work in areas that have already been fished for some time (Pet & Pet-Soede, 1999).

** Loss of live coral cover, in m² per 100 m² of reef per year.

reef. As the LRFFT in Indonesia may have been active for 10 years or so (Johannes & Riepen, 1995), it would be exaggerated to state that the LRFFT in Indonesia has already caused widespread damage to the coral reefs. Our best estimate for reef degradation caused by the LRFFT is 40 times lower than the rate of coral cover increase as observed in Komodo National Park (Central Indonesia), where live-coral cover increased by 2 m² per 100 m² of reef per year after enforcement of the ban of blast fishing (Pet & Mous, 1999). However, this comparison has to be regarded with caution, because increase in live-coral cover does not equal recovery to the state of a pristine coral reef, with its complex structures and its relatively high abundance of the longer-lived hard corals, such as some species of *Porites*. On the other hand, some reefs seem to be able to re-establish their complexity quickly after near-complete annihilation; after a volcanic eruption and destruction by the lava flow, the reefs around Banda (Eastern Indonesia) recovered completely after a period of five years, featuring 124 species and table coral colonies with a diameter of over 90 cm (Tomascik, van Woësik & Mah, 1996).

The damage done by the cyanide fishery for the much smaller sized, ornamental fish is probably much greater than that for food fish, as the number of target fish per unit of reef area is much higher. Also, mechanical reef destruction in the fishery for ornamental fishes may be more extensive, as branching corals are broken apart over large areas, in order to retrieve the small fish (pers. observ.). A relatively high estimate of reef loss inflicted by the fishery for ornamental fish (0.4% reef loss per year) was also suggested by McManus, Reyes & Nanola (1997).

The quantification of effects of cyanide squirts on biota other than the target fish and hard corals is hampered by the lack of field data. The risk of adverse long-term effects from cyanide fishing on the environment is probably low, as there are no reports of cyanide bio-magnification or cycling in living organisms (Eisler, 1991). Cyanide seldom persists in surface waters owing to complexation or sedimentation, microbial metabolism, and loss from volatilisation (Eisler, 1991). Our impression was that *around* the areas where we observed coral bleaching caused by cyanide fishing, there was no evidence for mortality in other benthic organisms. Hence, the estimates for reef degradation presented in Table 1 are likely to pertain to the amount of live-cover loss, including cover of benthic organisms other than hard corals, rather than to the loss of hard-coral coverage exclusively. Mortality in non-target fishes caused by cyanide fishing is even more difficult to quantify. Because of their higher metabolic rate per unit of body weight, smaller fish that were in the direct vicinity of the target fish at

the moment of capture most probably die. The mortality probably depends on the rate of dilution of the squirted cyanide, and on the amount of fish that were in the direct vicinity of the target fish. This unknown collateral damage is one of the reasons why we think that cyanide fishing should not be tolerated.

In the absence of scientific evidence that shows that the amount of reef degradation is higher than our observation of one square metre per cyanide-caught fish, we must conclude that the reef-degrading capacity of the cyanide-based LRFFT is not as obvious as is sometimes assumed. Therefore, there is a need to get the priorities right when deciding how to allocate reef conservation dollars. There are numerous threats to coral reefs that are beyond doubt (cf. Bryant *et al.*, 1998). Some of these threats, such as global warming (Hoegh-Guldberg, 1999), need to be addressed on a global scale, but others, notably blast fishing (Pet-Soede, Cesar & Pet, 1999) can be addressed cost-efficiently at a local level (Pet, 1997; Pet & Mous, 1999). We are of the opinion that, within the category 'destructive fishing practices for food fish', blast fishing deserves a higher amount of conservation effort than cyanide fishing. Blast fishing accounts for a loss in live coral cover of 3.75 m² per 100 m² of reef yearly (Pet-Soede, Cesar & Pet, 1999), which is about 75 times more than our best estimate, and still about 5–6 times more than our 'worst-case' estimate for the loss of coral cover due to cyanide fishing for food fish.

The second effect of the LRFFT, the depletion of grouper stocks in their fishing grounds (cf. Bentley, 1999) is more worrying from both conservation and fisheries perspectives. The specific nature of the market for live food fish, where rarity increases the price up to a level where it is economically sound to catch the very last specimen, puts the fish stocks that are targeted by the LRFFT at a high risk (Sadovy & Vincent, 2000). The grouper spawning-aggregation sites are easily located by the fishers, and the life-history characteristics of groupers (longevity and size-dependent sex change) make these stocks even more vulnerable to overexploitation (Sadovy, 1997; 1994a). Hence, the size-selective fishing methods practised in the LRFFT affect reproductive success of the exploited stocks in two ways: by extracting the more fecund larger individuals, and by affecting the sex ratio (Johannes *et al.*, 1999). As the target fish are mostly top predators, the LRFFT may also indirectly affect the reef fish community at the lower trophic levels through cascading effects in the food web that are known to exist in both temperate and tropical aquatic food webs (Carpenter, Kitchell & Hodgson, 1985; Goldschmidt, Witte & Wanink, 1993). The problem of over-exploitation cannot be solved by abating

cyanide fishing alone, as it is possible to deplete grouper stocks by other fishing methods (i.e., hook and line) as well (Sadovy 1993; 1994b). Therefore, it is our opinion that the overexploitation is a more severe problem than fishing with cyanide in the LRFFT. The problem of overexploitation can only be solved by putting a proper fisheries management and enforcement framework in place. We strongly support the recommendation in the recent TRAFFIC / WWF report (Lau & Parry-Jones, 1999) to protect spawning aggregations, but we regret that this recommendation is listed under 'Specific recommendations to address cyanide fishing'. Efforts to protect grouper stocks and other stocks targeted by the LRFFT should consider all fishing methods, not only cyanide fishing.

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Appendix

Short review on the traded volume of live food fish

Johannes & Riepen (1995, p.4) presented a conservative estimate of total volume of the LRFFT of 20,000–25,000 tonnes per year, and they estimated that about 60 per cent thereof is traded in Hong Kong (Johannes & Riepen, 1995, p. 16). A significant amount of the total volume is cultured, but it remains unclear to what extent the culture is based on the grow-out of wild-caught fish (Johannes & Riepen, 1995, p. 16). For example, the country that is known to produce most of the cultured groupers, Taiwan (Johannes & Riepen, 1995, p. 16) is also an important importer of wild-caught grouper fingerlings from the Philippines (Bentley 1999, pp. 29–30).

According to the survey of Hong Kong Census and Statistics Department (HK CSD) data by Lau & Perry-Jones (1999, pp. 8–12), the total amount of live marine fish (HK HS Codes 0301 99-12, -21, -22, -23, -29, -31, -39, -41, and -99) imported into Hong Kong amounts to 21,000 tonnes, whereof nearly 90 per cent was imported by air. This figure of 21,000 tonnes underestimates the total volume of the LRFFT, as locally licensed, live-reef-fish transport vessels, estimated to import about 10,000 tonnes per year (Johannes & Riepen, 1995, p. 51), are exempt from declaration of imports of live reef food fish (Lau & Perry-Jones, 1999, p. 4).

By interviewing 39 of the 114 companies that trade live fish in Hong Kong, imports of the 11 most common species were estimated at 24,000 tonnes per year (Lau & Perry-Jones, 1999, p. 7).

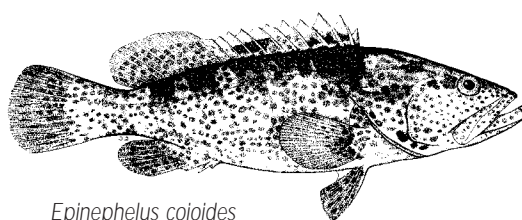
These species were: *Lutjanus argentimaculatus* (21%), *Epinephelus coioides* (20%), *Plectropomus leopardus* (18%), *P. areolatus* (9.7%), *E. bleekeri* and *E. areolatus* (both species grouped in one category, 7.6%), *E. fuscoguttatus* (7.2%), *E. polyphkadion* (5.0%), *E. akaara* (3.6%), *Cromileptes altivelis* (3.0%), *Cheilinus undulatus* (2.8%) and *E. lanceolatus* (1.9%).

Hence, according to the survey among traders, the total volume of live food fish traded in Hong Kong must have amounted to 32,000 tonnes annually. This is close to the sum of the estimate for the volume of live reef fish (10,000 tonnes) imported by locally licensed vessels (Johannes & Riepen, 1995, p. 51), and the total imports (21,000 tonnes) as estimated by the HK CSD (Lau & Perry-Jones, 1999, pp. 8–12), even though the latter includes a large category (c. 14,000 tonnes) of 'other live marine fishes' (Lau & Perry-Jones, 1999, p. 6). Perhaps problems with species identification caused a considerable part of the trade volume that should have been categorised in one of the other statistical categories to be entered under 'other live marine fishes'.

According to Hong Kong importers, Indonesia supplies more than 50 per cent of the wild-caught live reef fish to Hong Kong and Singapore (Johannes & Riepen, 1995, pp. 10 & 35). This figure was close to the estimate of 60 per cent from Bentley (1999, p. 28), which was based on fisheries statistics from the main exporting countries (Indonesia, Philippines and Malaysia).

In Lau & Parry-Jones (1999) Indonesia was listed as the only country that exported mouse grouper (*Cromileptes altivelis*) and giant grouper (*Epinephelus lanceolatus*), whereas it accounted for 35 per cent of coral trout and 20 per cent of all other groupers (Lau & Parry-Jones, 1999, pp. 8–10). However, as was mentioned earlier, these data pertain almost exclusively to imports by air.

According to the Indonesian Directorate General of Fisheries, annual exports of live food fish from Indonesia averaged 3,500 tonnes over 1995–1996 (Bentley, 1999, p. 29), whereas Erdmann & Pet (1996, p. 6) present an even lower estimate for total exports of live food fish from Indonesia of 2,200 tonnes annually.



Epinephelus coioides

