Monitoring the live reef food fish trade: Lessons learned from local and global perspectives

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There are widespread concerns that the live reef food fish trade (LRFFT) is causing overexploitation of populations of coral reef fishes (Johannes and Riepen 1995; Bentley 1999; Lau and Parry-Jones 1999; Sadovy et al. 2003; Hamilton and Matawai 2006). A major challenge for achieving sustainable management of the LRFFT is obtaining data needed to quantify the influence of the trade on the natural resource base and to accurately characterize the trade in terms of spatial and temporal patterns. Such information is necessary for monitoring the impact of the trade on particular species (for example to provide non-detriment findings required for trading the CITES Appendix II-listed humphead wrasse,[2] *Cheilinus undulatus*; Chu et al. 2006) and for informing management initiatives, both in existing fisheries and in countries where the trade has not yet arrived.

We have been involved in two recently published studies quantifying the dynamics and impacts of the LRFFT at two different geographic scales: first, we investigated the global dynamics and regional impacts of the LRFFT using Hong Kong import data (Scales et al. 2006), and second, we assessed the local impacts of the LRFFT on populations of coral reef fish in northern Borneo using fish catch data from traders (Scales et al. 2007). Due to the nature of the datasets collected, both of these studies provided insights into the temporal and spatial dynamics of the LRFFT. Here we give an overview of these two studies, highlighting the data collection methods used and the features of the datasets that made them especially useful in monitoring the LRFFT. Based on lessons learned from these studies we make recommendations for future monitoring of the LRFFT.

Analysing global trends in the LRFFT

The LRFFT has spread dramatically since its initiation in Hong Kong in the 1970s (Johannes and Riepen 1995; Sadovy et al. 2003). We recently looked in detail at historical data in order to quantitatively describe the dynamics of the geographic spread of the trade across countries. Despite the high value of the LRFFT, there is a relatively small volume of live reef fish traded internationally compared with other global fisheries. Consequently fisheries statistics rarely include live reef fish in a separate category (Cesar et al. 2000).

For our study, complete figures for imports of live reef fish to Hong Kong from 1988 to 2003 were collected directly from the Hong Kong Census and Statistics Department (CSD). This dataset went further back in time than the previously available Hong Kong import datasets, such as those used by Johannes and Riepen 1995, McGilvray and Chan 2002, Sadovy et al. 2003, and Muldoon et al. 2005. A shortcoming of the existing system for recording live reef imports into Hong Kong is the fact that approximately 100 locally licensed fishing and transport vessels are exempt from the declaration of imports of live reef fish (Sadovy et al. 2003; Muldoon et al. 2005). The total mass of live fish recorded by the CSD is therefore an underestimate of the total imports into Hong Kong. In 1998 a voluntary scheme was set in place by the Agriculture, Fisheries and Conservation Department (AFCD) to record volumes of live fish being imported by locally registered vessels. According to these AFCD statistics, between 1998 and 2002 the locally registered vessels that participated in this voluntary scheme imported an additional 13–53% of the fish biomass recorded by the CSD. It has been estimated that 60% of live reef food fish traded internationally is imported into Hong Kong (Sadovy et al. 2003), hence data on its imports are likely to be indicative of the dynamics and structure of the LRFFT as a whole. In addition, past trade studies have suggested that because Hong Kong is a duty-free port, its trade statistics are likely to reflect actual trade volumes more accurately than those from elsewhere, since there is little incentive to under-report declared imports in order to reduce tariffs (Lau and Parry-Jones 1999; Clarke 2004).

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2. International trade is permitted for species listed on Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) but only where it can be demonstrated that harvesting does not have a detrimental impact on wild populations.

Table 1. Revised trade categories of live reef fish imported to Hong Kong, as recorded in AFCD records from 1997 onwards.

Common name used by AFCD	FAO common name	Scientific name
Giant grouper	Giant grouper	*Epinephelus lanceolatus*
High-finned grouper	Humpback grouper	*Cromileptes altivelis*
Green grouper	Orange-spotted grouper	*Epinephelus coioides*
Tiger grouper	Brown-marbled grouper	*Epinephelus fuscoguttatus*
Flowery grouper	Camouflage grouper	*Epinephelus polyphekadion*
Leopard grouper	Leopard coralgrouper	*Plectropomus leopardus*
Spotted grouper	Spotted coralgrouper	*Plectropomus maculatus*
Humphead wrasse	Humphead wrasse	*Cheilinus undulatus*
Mangrove snapper	Mangrove red snapper	*Lutjanus argentimaculatus*

Before 1997, CSD trade data were only available as totals of "live marine fish" from a given exporting nation. However, since all the other import categories included freshwater and non-reef marine fish, we assumed that this "live marine fish" category represented mostly coral reef fish. Species-specific import data were available from 1997 onwards, following an initiative from the AFCD to revise the trade categories (Table 1).

Our newly compiled datasets included full information regarding the source nation of all the imports of live reef food fish into Hong Kong; those sources included 19 nations in Southeast Asia and the Pacific Islands.

Accelerating global expansion of the LRFFT

In order to assess the speed at which the LRFFT has spread away from Hong Kong, we collated available published start-up dates of the trade in individual exporting countries (Johannes and Riepen 1995; Bentley 1999) and measured the direct distance (in km) from the capital city of each exporting country to Hong Kong. These data indicated that the LRFFT has been spreading to new countries farther and farther away from Hong Kong at an accelerating pace: initially in the 1970s the trade expanded at a rate of about 100 km per year and by the late 1990s reached over 400 km per year (Fig. 1).

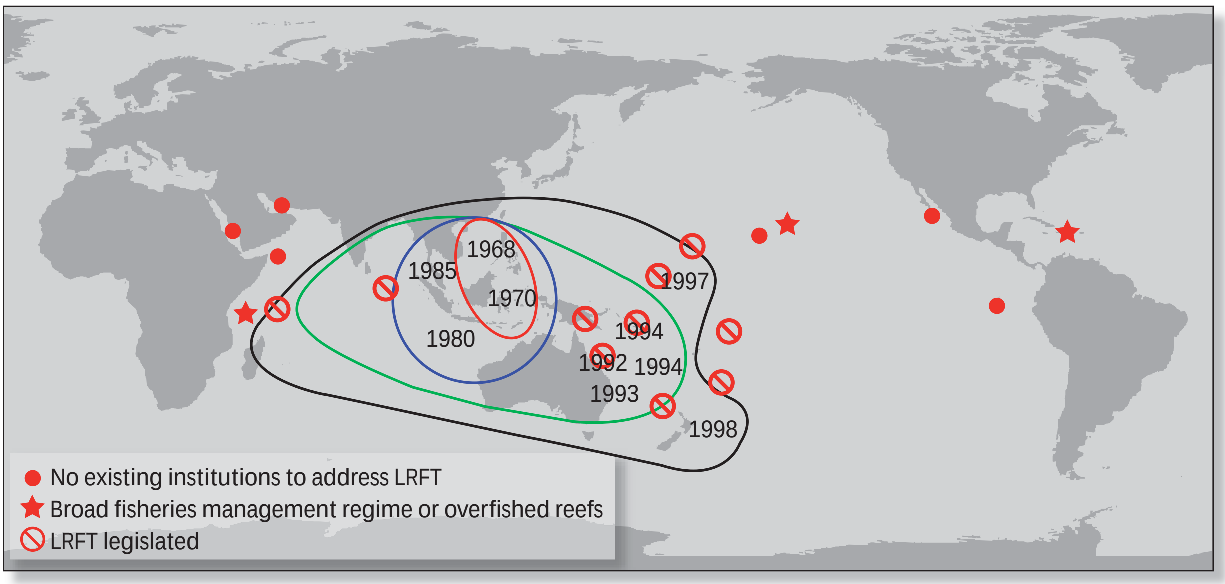

Figure 1. The global spread of the LRFFT, showing start-up dates for the trade in several areas and contours representing the area covered by the trade in 1970, 1985 and 1998. After Scales et al. (2007).

Boom-and-bust patterns

Boom-and-bust trends are often observed in marine and freshwater fisheries and have been reported in the LRFFT (Barber and Pratt 1998; Cesar et al. 2000; Clark 2001; Bruckner et al. 2003). When a potentially lucrative fishery resource is discovered in a particular area, such as when stimulated by new market demands or increases in price, fishing effort increases rapidly. Growing catches encourage other fishers to join the fishery, which expands rapidly (boom phase). In the absence of any management interventions, more and more fishers become involved in the fishery and soon fish populations are unable to replenish themselves rapidly enough to maintain catch rates; fish populations crash, catches fall, profits fall and the fishery collapses (bust phase). We looked at LRFFT trade data to search for boom-and-bust trends and investigated the magnitude of the boom phases and the location and timing of boom-and-bust trends.

We defined a boom-and-bust trend to be one in which there were data showing at least five years of trade, during which there was an increase in annual export weight over at least three years (boom phase) followed by at least two years in which the annual weight declined each year (bust phase) (Fig. 2a). If in a given case the data showed more than five years of trade activity, it was still defined as a boom-and-bust trend if the boom-and-bust phases were interrupted by no more than two deviations from the overall trend (i.e. there were small year-to-year decreases or increases) (Fig. 2b). At the end of a boom-and-bust phase, according to our definition, the volume of trade is low but not necessarily zero. Where there were gaps in the dataset for a particular source nation, we assumed that there was no departure from the general trends.

Out of 19 source nations studied, 10 clearly showed a boom-and-bust pattern of development. Worryingly, the booms appeared to be increasingly ephemeral for countries farther from Hong Kong, with shorter boom phases (time between the start-up of the trade and the peak in trade volume). This was not explained by the more distant countries having smaller reefs and hence potentially smaller pre-LRFFT populations of targeted species: the time between start-up to peak was found to be unrelated to reef area.

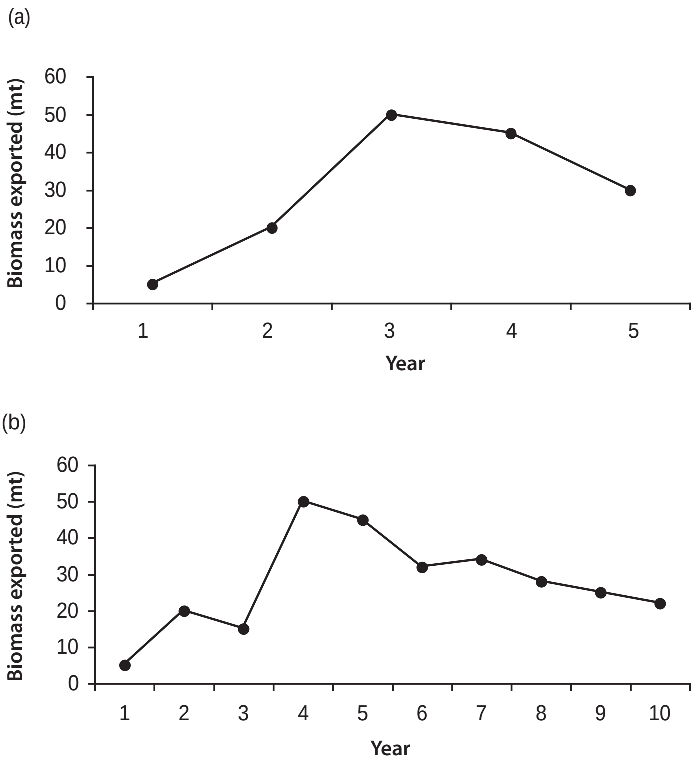

Figure 2. Illustration of minimum requirements for a boom-and-bust trend (as defined in Scales et al. 2006 and here) with: a) five years of export data, and b) more than five years of export data.

Fishing down the price list

We also analysed the data by species instead of by source nation. Species-specific import figures from 1997–2002 were summed from CSD and AFCD datasets to provide total annual import figures for each species across all source nations combined. These data revealed the serial depletion of species in trade in descending order of price (based on ranking of prices paid to fishers in the main exporting countries in 2001; Sadovy et al. 2003) with more expensive species such as humphead wrasse and giant grouper undergoing bust phases first, followed by lower-priced species such as leopard coralgrouper and spotted coralgrouper.

What happens next to the LRFFT globally?

Taken together, these three main findings from our global study — the increasing pace of trade expansion, accelerating boom-and-bust trends, and fishing down the price list — pose a worrying scenario for nations located at the periphery of the current trade. At particular risk are Pacific nations with reef ecosystems that so far remain comparatively healthy and sustainably managed, since their relatively large distance from Hong Kong may not be enough to protect these nations from being the focus of attention of the expanding wave of the LRFFT. An issue raised by Berkes et al. (2006) was the threat posed by mobile fishing fleets that enter countries and rapidly deplete resources before regional or national institutions can address issues of overexploitation. Understanding the global dynamics of the LRFFT is crucial to help pre-empt its continued expansion and to encourage countries to enter the trade under a controlled and precautionary basis. It is extremely encouraging that through the Secretariat of the Pacific Community's (SPC) Pacific Regional Live Reef Fish Trade Initiative, several countries have begun to approach the LRFFT in a precautionary way, introducing small-scale trial fisheries and developing LRFFT management plans (Yeeting 2006). There also remain some worrying gaps within existing regional coordination of fisheries management institutions for nations in the Indo-Pacific region, including those bordering the Red Sea, Persian Gulf and in the far eastern Pacific (Fig. 1). Reefs in these nations could well become attractive to the LRFFT in the near future; in our view these countries' fisheries would benefit greatly from following a management and conservation model such as that developed by the SPC.

Local impacts

Having looked at the wide scale, country-by-country trends in the LRFFT, we also investigated the local impacts of the LRFFT on populations of coral reef fish (Scales et al. 2007). The geographic focus for this study was the Malaysian state of Sabah on the northern tip of Borneo (Fig. 3). The LRFFT has operated in this region since the 1980s with a supply chain structure broadly representative of other live reef fisheries in Southeast Asia (Bentley 1999). There are two main types of fishing operations around the northwest coast of Sabah and offshore islands. First, individual fishers operate from small wooden boats, using hook and line to catch fish from reefs up to one day's journey from their home villages. Middlemen based in the villages buy live fish at a considerable premium (compared with prices for the same species dead). Traders send consignments of live fish to the town of Kudat on the mainland (Fig. 3). Second, larger vessels owned by live fish traders also operate out of Kudat, taking around 20 men to sea for up to 12 days at a time into the waters of the South China Sea and the southwest Philippines. Fish are caught using either handlines from the surface or underwater using surface-fed *hookah* diving gear. None of the fishers or traders we visited in Sabah spoke of using cyanide, which is not unexpected given the illegal nature of this fishing technique; however, there was anecdotal evidence that cyanide is used (Barber and Pratt 1997). Consignments of live fish from Kudat are transported by road to the state capital, Kota Kinabalu, bound either for consumption in local up-market seafood restaurants or for export by air to Singapore and Hong Kong.

Data collection in northern Borneo

During our research in the area, we discovered that some LRFF traders kept continuous records of the daily fish catches bought from individual fishers and vessels, either in record books or as copies of cash receipts given to fishers. These records included the date of sale, the name of each fisher or vessel registration number, the local name for each species bought, the total weight (kg) of each species (but not the number of individual fish), and the price per kg paid for each species. Several traders were willing to let us study their receipts and record books on the understanding that we were conducting independent academic research. We were able to gain access to these scientifically valuable datasets only because we worked closely and openly with local fishers and traders.

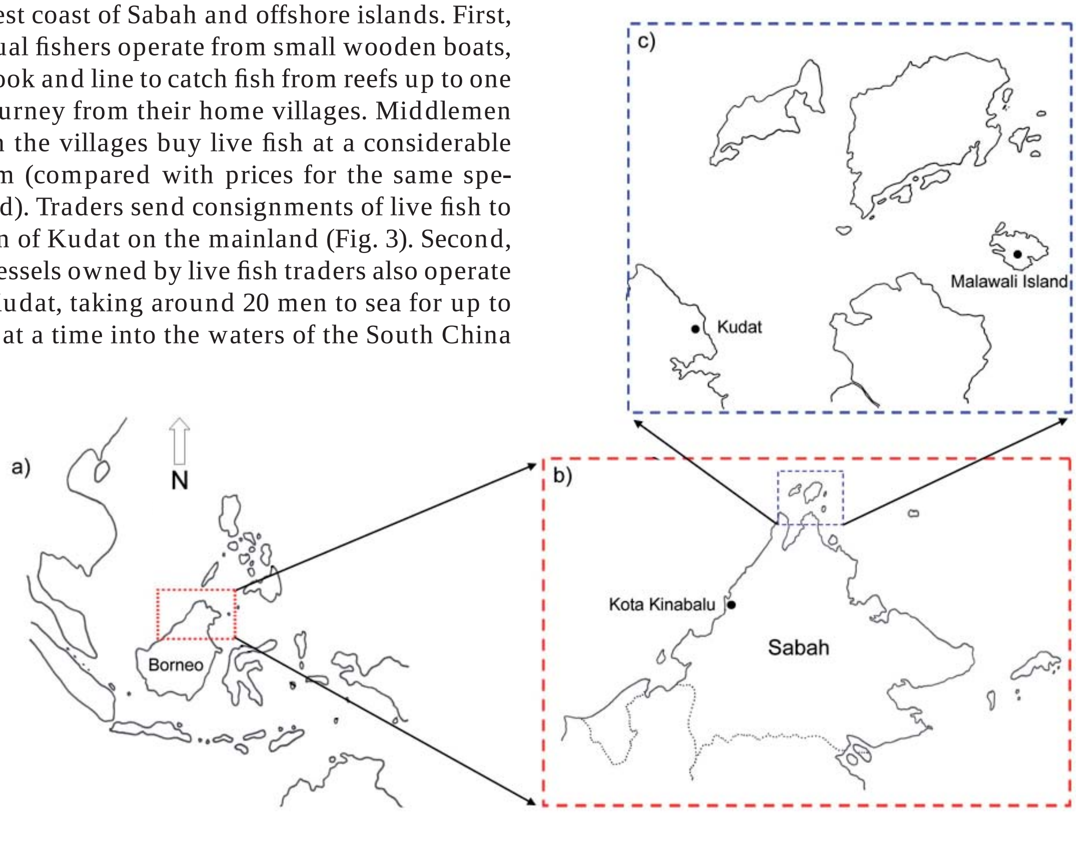

Figure 3. Maps of a) Southeast Asia, b) Sabah and c) north coast of Sabah.

Daily fish catch data were collected in 2002, 2003 and 2004 from two of the nine main traders in the mainland town of Kudat (these data represented about 30% of the overall trade in Kudat during that period) and from the single trader based on the island of Malawali (Fig. 3). The dataset covering the longest period was from one trader in Kudat: it included continuous catch data from January 1995 to January 2003 (excluding January 1998 through July 1999, due to a missing record book). The second Kudat trader provided data from November 1999 to June 2003. The Malawali trader provided catch receipts from August 2001 to August 2003.

For each of the three datasets we calculated the daily total catch (kg) of each species. Catch-per-unit-of effort (CPUE) was calculated by dividing these daily totals by the number of fishers (in Malawali) or vessels (in Kudat) operating each day. Each fishing trip from Kudat represented a consistent unit of fishing effort since there was no significant change over time in the length of trips made by vessels. Trip length in Malawali was always one day. In order to test for any significant changes in biomass of targeted species in the wild over time, we summed the fish catch data into monthly figures, which allowed us to subsequently take seasonal effects into account. We then used linear regression models on the monthly data to analyse temporal changes in total catch and CPUE for each species for each of the three traders. We assumed that CPUE is positively related to biomass in the wild and hence is a reasonable proxy for estimating relative abundance of species.

Local depletion of coral reef fish

We found that the total monthly catches in the longest dataset declined significantly for all species between 1995 and 2003 (Table 2). Despite a decline in the number of vessels selling fish to this trader over the same time period (which may reflect a general downturn in the fishery, a view that is backed up by informal interviews with fishers and traders in the region), CPUE also declined for three species – humphead wrasse, *Epinephelus* spp. and humpback grouper. We interpret the declines in CPUE of these species as quantitative evidence for population impacts of the LRFFT.

Results from the shorter datasets were less clear-cut. Total monthly catches in the medium dataset declined significantly for all species except spotted coralgrouper. However, the number of vessels selling to this trader also declined — in this case to such an extent that it explained the declines in total catches, since none of the species showed declines in CPUE. Patterns in the short dataset were very unclear. The only significant temporal change was an increase in the total monthly catch of humphead wrasse.

We tested whether differences in results across datasets were likely due to their different lengths by truncating the longest dataset so that it only spanned the years included in the medium or short datasets. Doing so removed all the significant patterns that were detected in the long dataset, thus confirming that the lack of patterns in the other time series was probably due to their short coverage, which only provided information on the bust phase. We also lumped all the species together in each of the three datasets and looked for trends. For the long and medium datasets there was still a significant decline in total monthly catch, but there were no significant declines in CPUE.

By gaining access to these highly detailed datasets, we were able to demonstrate just how rapid and drastic catch declines of species in the LRFFT can be. The declines were species-specific, took place in less than a decade, and are especially worrying given the mobile nature of the Kudat fishing fleet: it is likely that when the most accessible populations became depleted, the fishery ranged farther and, thus, maintained catches and catch rates for a longer period than they otherwise would have. In other words, the declines we observed at points of sale masked greater declines at points of capture. The masking of serial depletions by spatial shifts in exploitation range is a major obstacle in assessing the impacts on fish populations of mobile fishing fleets (Berkes et al. 2006).

The declines in biomass of LRFFT species we have inferred from declines in CPUE could have been caused by overfishing or by habitat degradation. However, it is unlikely that these declines were a consequence of widespread declining reef health, since the reefs around Borneo were relatively unaffected by the 1998 global coral bleaching event (Wilkinson 2000). Also, as described above in our study of global dynamics, the international trade data showed that stocks of LRFFT species did not simultaneously decline but were serially depleted according to distance from Hong Kong and price. The species targeted by the LRFFT in northern Borneo do not appear in local markets (A.M. and H.S., pers. observs.) and we therefore believe the LRFFT is the main source of fishing mortality for these species.

Given that the LRFFT is generally legal (which facilitates data collection), and that the structure of the supply chain is similar throughout Southeast Asia and beyond (e.g. traders outside Sabah, such as in Indonesia, are also known to issue cash receipts; Bentley 1999), it is likely that other daily catch datasets could be collected from fishers and traders to further investigate the impacts of the trade on local fish stocks.

Table 2. Temporal changes in total monthly catch and CPUE for fish species bought by three LRFF traders in northern Sabah (from Scales et al. 2007).

	Total catch			CPUE		
	Long dataset (8 years)	Medium dataset (3 years)	Short dataset (2 years)	Long dataset (8 years)	Medium dataset (3 years)	Short dataset (2 years)
Humphead wrasse	↓	↓	↑	↓	↔	↔
Leopard coralgrouper	↓	↓	↔	↔	↔	↔
Epinephelus spp.	↓	↓	↔	↓	↔	↔
Spotted coralgrouper*	↓	↔	↔	↔	↔	↔
Blacksaddled coralgrouper**	↓	No data	No data	↔	No data	No data
Squaretail coralgrouper[†]	↓	No data	No data	↔	No data	No data
Highfin coralgrouper[††]	↓	↓	No data	↓	↓	No data

Red arrow = significant decline ($p < 0.05$), green arrow = significant increase, white horizontal arrow = non-significant ($p > 0.05$).
**Plectropomus maculatus*, ***Plectropomus laevis*, †*Plectropomus areolatus*, ††*Plectropomus oligacanthus*

Recommendations for monitoring the LRFFT

Despite focusing on two contrasting geographic scales of the LRFFT, the datasets used in these two studies share some features that lead to important recommendations for future data collection that can be used for impact assessment throughout the LRFFT:

1. Catch or trade datasets need to cover as long a time period as possible.

This is necessary to increase the likelihood of detecting changes in catches and CPUE as well as boom-and-bust patterns of fishery development. Truncating our longest dataset in the northern Borneo study removed all the significant patterns that were apparent in the original, eight-year, time series.

2. Catch or trade datasets need to be as disaggregated as possible, both spatially and by species.

The disaggregated nature of the northern Borneo datasets was due to our having collected information directly from traders and not from further along the supply chain, such as consignments leaving from Kudat by road or from Kota Kinabalu by air. If we had done that, the data would not have been broken up into individual days, with information on particular fishing vessels and fishermen, meaning that effort and therefore CPUE would have been difficult or impossible to calculate. At a broader scale, even though the Hong Kong trade data were in some senses highly aggregated into annual trade volume from each country, they still provided details of fish species and country of origin and thus remained useful in gaining a widespread picture of the dynamics of the trade.

3. An estimate of harvesting effort (e.g. in terms of fishing trips, as in this northern Borneo study) can be crucial for interpreting catch data (i.e. estimating CPUE) and determining local impacts (i.e. using CPUE as an indicator for in-water stock biomass), but the lack of such information does not preclude the use of catch data for determining broad trends, especially when it is possible to compare local datasets across regions, as in our global study.

Again, our ability to estimate levels of fishing effort in the northern Borneo fishery was due to the fact that we collected daily fish catch data, from which we were able to determine the number of fishing trips undertaken to catch a given biomass of fish and hence make reasonable estimates of effort.

4. It is possible that there were other factors that could have influenced the trends in live food fish exports that were not apparent in the relatively crude import data used in the global study. However, the regional perspective these data provided was important for putting local

changes into a wider context. Therefore, data collected for purposes other than fisheries management, such as customs data, can be useful.

5. Similar datasets to those compiled in these studies should be collected where possible to help further understand the temporal and spatial dynamics of the LRFFT.

For example, other points of importation may hold trade data that could be analysed in the same way as the Hong Kong data were here. It would be useful to update estimates of the respective shares of the global live reef fish market that each main importing nation / city accounts for.

To effectively regulate the trade in threatened species it is important to be able to determine whether or not the trade is having a detrimental impact on wild populations. For example, trade in CITES Appendix II-listed humphead wrasse should now only take place from exporting nations that have demonstrated (through non-detriment findings) that the LRFFT is not impacting wild populations (Chu et al. 2006). Assessing the status of naturally rare and widely dispersed species — for CITES non-detriment findings or any other management or conservation programmes — is extremely challenging. Species-specific catch data, such as those collected in northern Borneo, are very useful in investigating local impacts of the LRFFT. It is possible that other coral reef fish species could, in the future, be listed in CITES appendices or protected under national legislation, which would bring about the need for similar levels of monitoring.

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