EM 531 Project Report

Coral reefs in East Timor: an investigation of the impacts of fishing on reef fish abundance

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Christo Rei Headland at sunrise, Dili, East Timor
(study sites D1 and D2 are to the west of the headland)

Abstract

The world's coral reefs are threatened by human activities, with fishing taking precedence over all other threats. Degradation of coral reef communities as well as physical destruction of reefs themselves has been much faster in areas close to major population centres. This study was undertaken to investigate impacts of fishing on fish abundance on the north coast of East Timor with the aim of testing the null hypothesis that abundance of reef fish targeted by fishing is no different further from versus close to dense human populations. The study also undertook a preliminary comparison of survey results with those from a global reef survey to test the null hypothesis that the impacts of fishing on abundance of reef fish in East Timor are no different to those in other reefs in the Indo-Pacific. Estimates of fish abundance were made by Underwater Visual Census (UVC) using stationary point counts, with two locations, one close to the densely populated capital, Dili, and one outside Dili, with three sites at each location, and three point counts undertaken per site. The results of the study provide evidence that fishing is impacting on fish abundance on coral reefs in East Timor. The study found significantly higher ($P<0.05$) abundance of snappers, parrotfish >20 cm, combined parrotfish size classes, and family richness outside Dili. No significant difference in grouper abundance, and abundance of parrotfish <20 cm between locations was found. Multivariate analyses using multidimensional scaling (MDS) ordination and ANOSIM found a significant difference in fish abundance between locations. It was not possible to conclude whether East Timor's reefs are in particularly good condition: comparison with global reef survey data indicate that this is unlikely to be the case. There is clearly a need for further research and ongoing monitoring of the impacts of fishing on coral reef communities in East Timor, and a strong imperative for the establishment of marine protected areas (MPAs).

Introduction

Continually rising human populations are having a significant impact on coral reefs worldwide (Tomascik *et al.* 1997). Byrant *et al.* (1998) consider that 58% of the world's reefs are threatened by human activity, with 80% of South East Asia's reefs at risk, particularly from coastal development and fishing. According to Jackson *et al.* (2001), fishing precedes all other pervasive human disturbances to coastal ecosystems. A global survey of over 300 reefs in 31 countries found that overfishing has reduced fish and invertebrate indicator organisms to low levels at most reefs, including those within marine protected areas (Hodgson 1999). In relation to the Nusa Tenggara region, where East Timor is located, Monk *et al.* (1997) write that there are indications that fish populations are being overexploited and are generally declining, with particular impact on several economically valuable species. Destructive fishing techniques including dynamite and cyanide fishing, as well as increasing human populations are contributing to this decline (Monk *et al.* 1997).

Reefs contribute significantly to the economies of many tropical countries, supporting important fishing and tourism industries. Coral reefs are the source of many varieties of food, and sustain the livelihoods of many coastal communities. Local fishermen fish mostly for their own daily consumption (Monk *et al.* 1997). It is estimated that there are 20,000 fishermen in East Timor, over half of whom depend on fishing as their main source of food and income (Jasarevic 2002).

Reefs far from human populations are expected to be in better condition than those near them. According to Tomascik *et al.* (1997) degradation of coral reef communities as well as physical destruction of reefs themselves has been much faster in areas close to major population centres. Despite this, even isolated reefs have been found to have low level of indicator species (Hodgson 1999).

This study used a point count underwater visual census (UVC) method to investigate the impacts of fishing on fish abundance in fringing reefs on the north coast of East Timor. This study aimed to test the null hypothesis that abundance of reef fish species targeted by fishing is no different closer to versus further from dense human populations. Prior to undertaking the study, it was predicted that the abundance of species targeted by fishing would be significantly lower close to dense populations.

This study also aimed to provide a preliminary comparison of results with those from a global reef survey published by Hodgson (1999) to test the null hypothesis that the impacts of fishing on abundance of reef fish in East Timor are no different to those in other reefs in the Indo-Pacific. It was predicted that impacts from fishing would be lower in East Timor in comparison to other reefs in the Indo-Pacific because of limited development of commercial fishing in East Timor.

Study Area

The study was conducted on fringing reefs on the north coast of East Timor. Fringing reefs, (reefs which closely follow the shoreline), form an almost continuous strip along the coast of East Timor (Monk *et al.* 1997). The topography of fringing reefs along the north coast of East Timor ranges from gentle slopes to sheer walls (G. Kintz 2003, pers. comm. 27 March).

The artisanal reef fishery on the north coast of East Timor is largely exploited by subsistence fishermen. The principal gear used are nets, with hand-lining and spear fishing undertaken to a lesser degree. There is currently no regulation of net mesh size. Dynamite fishing is practiced to a limited extent, but was previously more prevalent (A. de Jesus 2003, pers. comm., 5 June 2003). There are currently no marine protected areas (MPAs) in East Timor. Traditional systems are in place in some areas, with locally enforced no take periods, known as *tara bandu* (A. de Jesus 2003, pers. comm., 5 June 2003).

Study site

The most densely populated area in East Timor is the capital, Dili. Sites closer to Dili are subject to higher fishing pressure than sites outside Dili due to the high population concentration in Dili (A. de Jesus 2003, pers. comm., 5 June 2003). To compare the fish abundance closer to versus further from dense human populations, three (3) study sites close to Dili and three (3) study sites more than 25 km from Dili were chosen (Fig. 1). Each site comprised a 150 m length of reef. To reduce variability between sites, only sloping reefs were selected. The only sloping reefs sites close to Dili are reefs east and west of the Christo Rei headland east of Dili. The sites close to Dili, referred to hereafter as Dili (D) location were;

Site D1: Squiggle Rock (8° 33'S, 125° 37'E), 5 km east of Dili,

Site D2: Christo Rei beach (8° 32'S, 125° 37'E), 6 km east of Dili,

Site D3: Grenade beach (8° 32'S, 125° 38'E), 6.5 km east of Dili.

The study sites more than 25 km east of Dili, referred to hereafter as outside Dili (OD) location were;

Site OD1: Secret Spot (8° 29'S, 125° 50'E), 35 km east of Dili,

Site OD2: Behau beach (8° 29'S, 125° 51'E), 37 km east of Dili,

Site OD3: K41 (8° 29's, 125° 53'E), 41 km east of Dili.

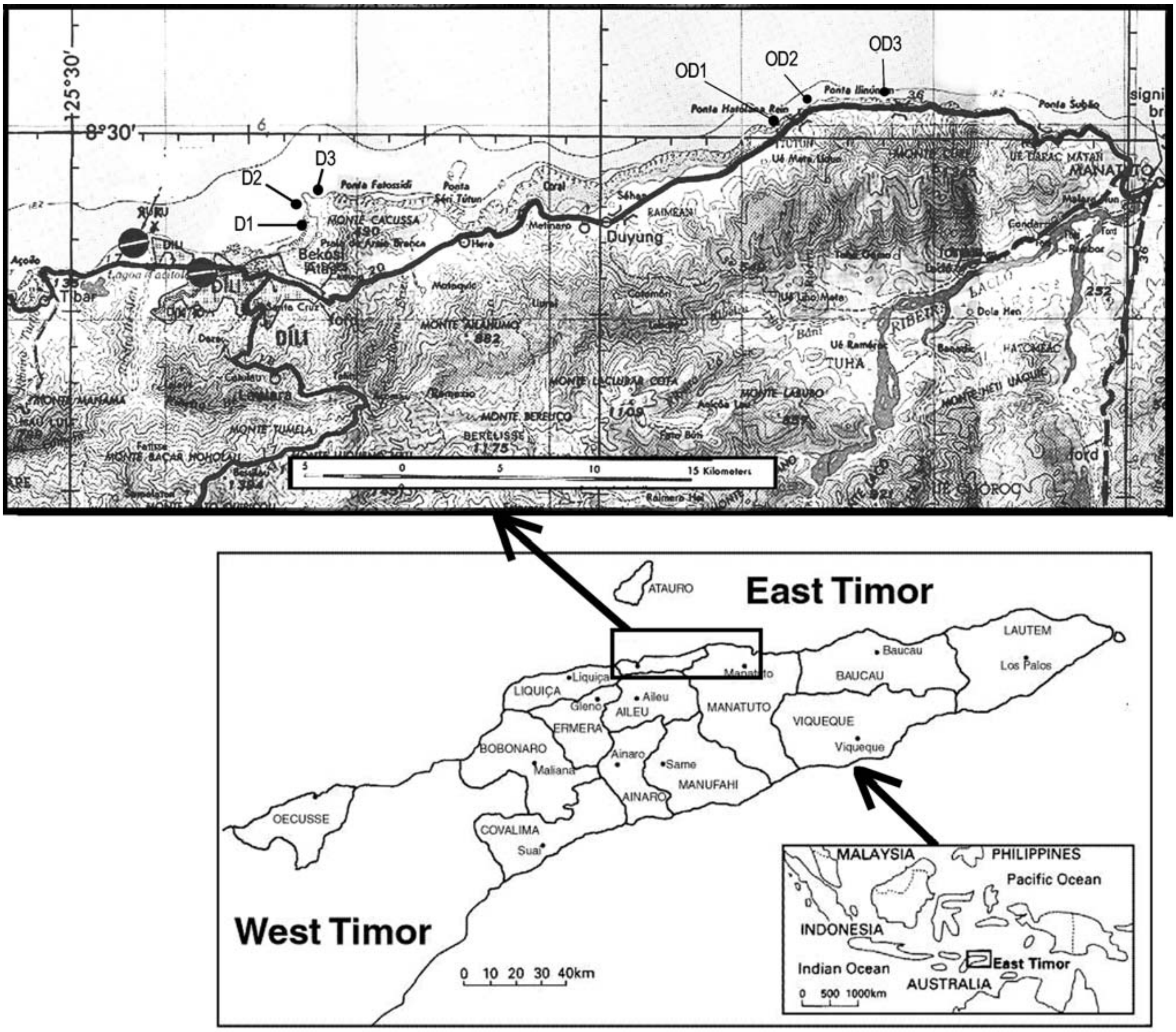

Figure 1. Location of the six reef survey sites on the north coast of East Timor. Location Dili (D), outside Dili (OD).

Methods

Underwater visual census (UVC) method

Estimates of fish abundance were made by UVC using stationary point counts over 6 dives from the 18th-25th of May 2003. Point count methods were based on Samoilys and Carlos (1999) and Santos *et al.* (2002) and were refined in consultation with marine biologist Belinda Curley. Three randomly located point counts were undertaken at each of the six study sites[1] by two divers[2].

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[1] The number of samples was chosen based on minimum requirements for a survey (A. Boutlon 2003, pers. comm., 27 March), rather than being determined by a pilot study, due to time constraints.

[2] As required by recreational diving licence.

Point counts had 9 m radii and were all located at 10 m depth. The boundary was estimated by the second diver extending a 9m rope held at the centre of the count by the observer. A radius of nine metres was chosen as this was within the range of visibility (Samoilys & Carlos 2000). To allow fishes to habituate to the divers, as recommended by Perrow *et al.* (1996), the count was started two minutes after extension of the rope. During this period, the observer stayed in the middle of the count area and recorded count site covariate information. Substrate categories; hard coral, soft coral, live coral, dead coral, other (sessile organisms such as anemones, feather stars, and ascidians), sand, rubble, and coral bleaching were ranked as none (1), low (2), medium (3), and high (4).

Each fish count was undertaken for 10 minutes. The observer rotated around the axis of the centre of the count area, with all targeted fishes recorded that were inside/entered the count area during the count time. Care was taken not to count the same individual twice. Five minutes were then spent searching the count area for cryptic species. Lobster (Palinuridae Family) and giant clams (Tridacnidae Family) observed were also counted.

Target species

The species selected for this study were those likely to be exploited for commercial and subsistence purposes. Choice of species was based on Monk *et al.* (1997), Reef Check (n.d), and a survey of the Dili fish market undertaken on the 30th of March 2003.

Species belonging to the following families were targeted in this study; Serranidae (groupers), Scaridae (parrotfish), Lutjanidae (snappers), and Haemulidae (sweetlips). Humphead (Napolean) Wrasse *Cheilinus undulates* (Labridae) were also targeted. Fishes, except *C. undulates,* and the scarid *Bolbometopon muricatum* (Bumphead Parrotfish) were identified only to family level. Size classes were recorded only for parrotfish and groupers, with parrotfish recorded as <20cm/>20cm, and groupers as <30cm/>30cm. A 30 cm long reference stick, marked at 20cm was used to assist with estimation of fish size (as per Reef Check n.d.). As recommended by Reef Check (n.d.), any sitings outside count areas of *C. undulates* and *B. muricatum* were to be recorded. Fish were identified using two field guides: Allen (1997) and Allen & Steene (1999).

Temporal variation

To account for temporal variation, it was aimed to undertake all surveys around the middle of the day (late morning and early afternoon). However, this was not achieved for site OD3 due to transport constraints, and site D2 due to tide constraints (this site required entry required at high tide). These sites were sampled between four and five p.m..

Data analysis

Fish abundance and richness were compared between sites closer to and further from Dili using univariate and multivariate techniques[3]. The computer packages used were Statistix7 and Primer respectively.

Abundance and richness[4] data for each family were plotted as averages with standard error bars in histogram form for Dili versus outside Dili locations. The univariate analyses were undertaken using nested ANOVA, to take into account decreased independence of point counts within sites (A. Boulton 2003, pers. comm., 31 May). Sweetlip data were not analysed, as sweetlips were recorded in only one point count. Parrotfish and grouper data were analysed for separate and combined size classes.

Before proceeding with the ANOVA, data were examined for homogeneity of variance (P<0.05) using Bartlett's test[5], and for normality using Shapiro-Wilk test. Data were transformed where the Shaprio-Wilk test result was higher than 0.82. 0.82, rather than 0.85 was chosen because of the lack of a suitable non-parametric test for nested data. Snapper data were log(x+1) transformed. Grouper data for size >30cm, richness data and all parrotfish data were rank transformed. Rank transformed data were still non-normal (Shapiro-Wilk test result <0.85).

A classification was undertaken, by converting a species by sample primary matrix to a similarity matrix using the Bray-Curtis similarity coefficient. Data were subject to square root transformation. The similarity matrix was subject to cluster analysis, using average linkage.

The ordination method used was multidimensional scaling (MDS). Stress values of less than 0.20 were considered valid representation of the similarity matrix (A. Boulton 2003, pers. comm., April 29). Covariate substrate and giant clam data were overlayed, using 'bubble' plots on the MDS ordination to show associations between fish samples and covariate data. ANOSIM was used to determine whether there was a significant difference between Dili and outside Dili fish samples, with fish values and location (Dili/outside Dili) as the fixed factors.

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[3] Mulitvariate analyses were undertaken by Associate Professor Andrew Boulton.

[4] Richness was measured by summing the number of families recorded at each point count.

[5] This test is part of one-way ANOVA in Statistix, and was used as there is no test for homogenisation of variance for the nested ANOVA. The results were therefore indicative only.

Data were compared to the results of the global reef survey published by Hodgson (1999). Data available were frequency distributions (percentage) of sites by abundance classes. The data from this East Timor survey were pooled by site (three point counts), and allocated to the abundance classes as per the global reef survey. Histograms were plotted using Excel to compare data sets.

Results

No Humphead wrasse and Bumphead parrot fish were observed during the study, and sweetlips were recorded in only one point count (two individuals). No large groupers were observed during the study, with groupers in the >30cm size class around 30-35 cm in length. Figure 2. summarises results of fish counts showing mean number (+/-s.e.) of fish per family per location.

Nested analysis of variance

The conventional significance threshold of $P<0.05$ was used for this study. Bartlett's test indicated that richness, grouper and snapper and pooled parrot fish data had homogeneous variances. Parrot fish size class data could not be tested due to group variances of zero.

The mean number of snappers was found to be significantly higher further away from Dili ($F_{1,12}=13.00$, $P=0.0036$).

The number of groupers of separate and combined size classes did not differ between locations[6]. Results of nested ANOVAs for groupers were; <30 cm ($F_{1,12}=0.10$, $P=0.7573$), >30cm ($F_{1,12}=0.15$, $P=0.7096$), and for all groupers ($F_{1,12}=0.04$, $P=0.8417$). However, there was significant variation between study sites in median number of groupers <30 cm ($F_{4,12}=7.60$, $P=0.0027$), and all groupers ($F_{4,12}=6.08$, $P=0.0065$) indicating that abundance of groupers was highly variable.

No significant difference in median parrotfish abundance was found between locations for parrotfish <20 cm ($F_{1,12}=1.99$, $P=0.1833$). The median number of parrotfish was found to be significantly higher outside Dili: parrotfish >20 cm ($F_{1,12}=24.85$, $P=0.0003$) and for all parrotfish ($F_{1,12}=5.33$, $P=0.0395$).

Analysis of richness found the median family richness to be higher further away from Dili ($F_{1,12}=5.91$, $P=0.0317$), as shown in Figure 3. Parrotfish <20 cm results should be interpreted with caution as data were strongly non-normal.

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[6] Untransformed data were used for the smaller size class, therefore means were compared, while rank transformed data were compared for all groupers, and combined size classes, thereby comparing medians.

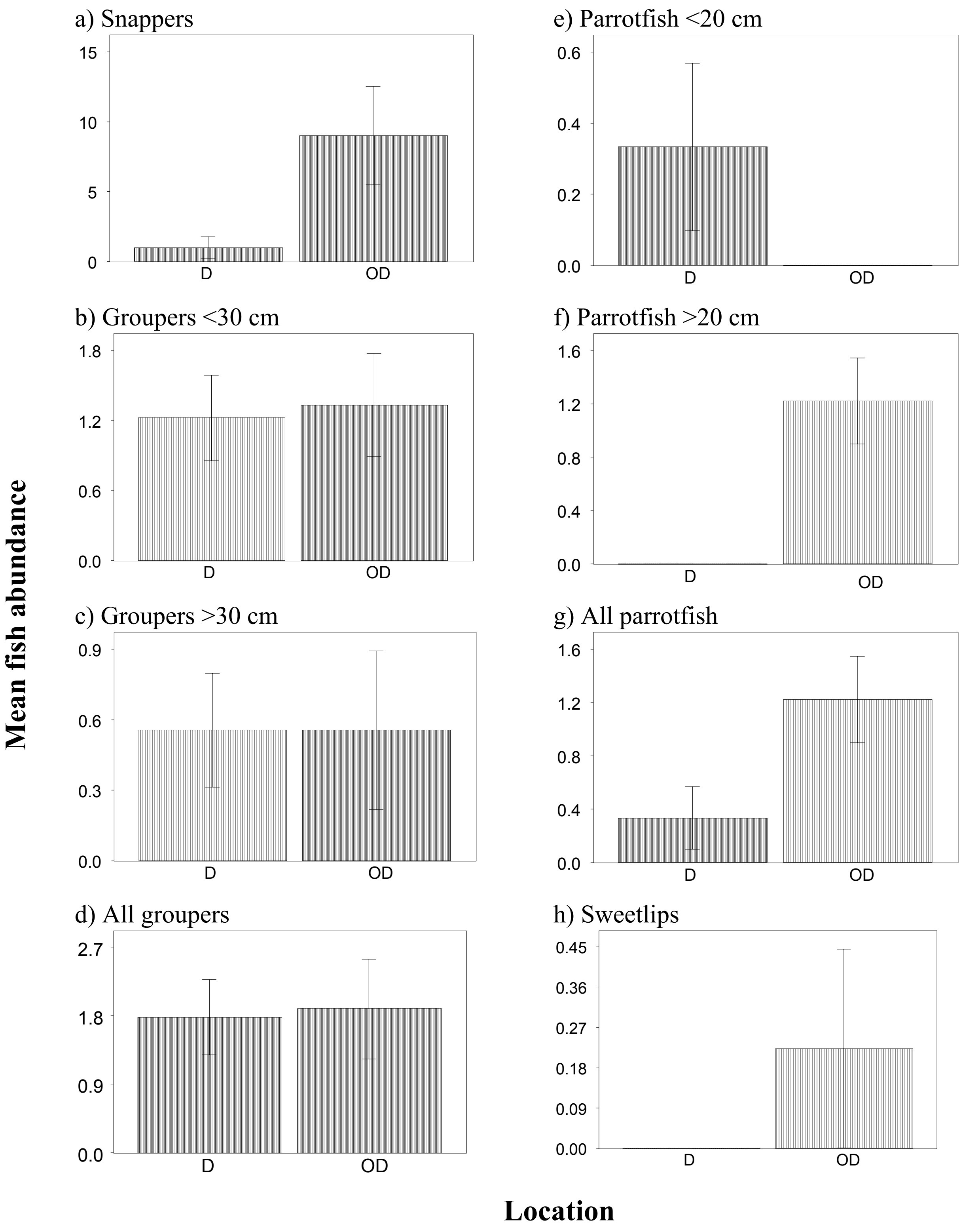

Fig. 2. Mean abundance (+/-s.e) of fish families. Abundances are shown for location; Dili (D) and outside Dili (OD). Each location represents three sites with three point counts.

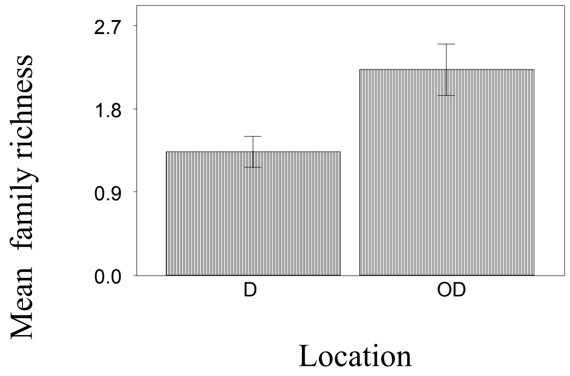

Fig. 3. Mean richness (+/-s.e) of fish families. Richness is shown for location; Dili (D) and outside Dili (OD). Each location represents three sites with three point counts.

Multivariate analysis

The multivariate analyses indicate that Dili sites are generally more similar to other Dili sites, with the same true for sites further from Dili. One site (OD21) was grouped on its own, and Dili site D11 was more similar to sites outside Dili. The ordination plot is shown in Figure 4. It has a stress level of 0.09, therefore is considered to be a valid representation of similarity. Results of ANOSIM indicate a significant difference in fish abundance between locations (R=0.374, P=0.004).

Covariate data did not strongly differ between locations (Figure 5). Only one lobster was counted (at a site close to Dili), a total of six clams were counted (three each at, Dili and outside Dili sites). Slightly more dead coral and rubble were associated with Dili sites while slightly more sand, live coral and hard coral were associated with outside Dili sites. More non-coral sessile organisms were found outside Dili (other). No difference between locations was found for soft coral.

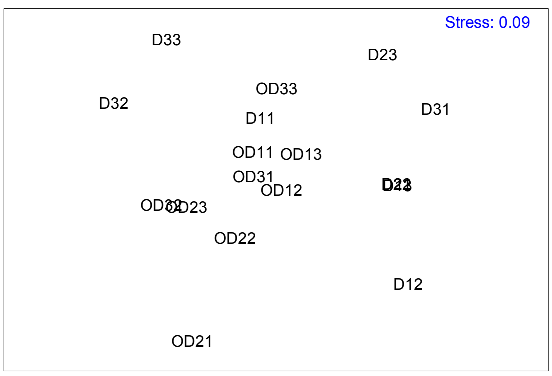

Fig. 4. MDS ordination plot with fish values and location [Dili(D), outside Dili (OD)] as the fixed factors, with stress of 0.09. ANOSIM indicated a significant difference in fish abundance between locations (R=0.374, P=0.004).

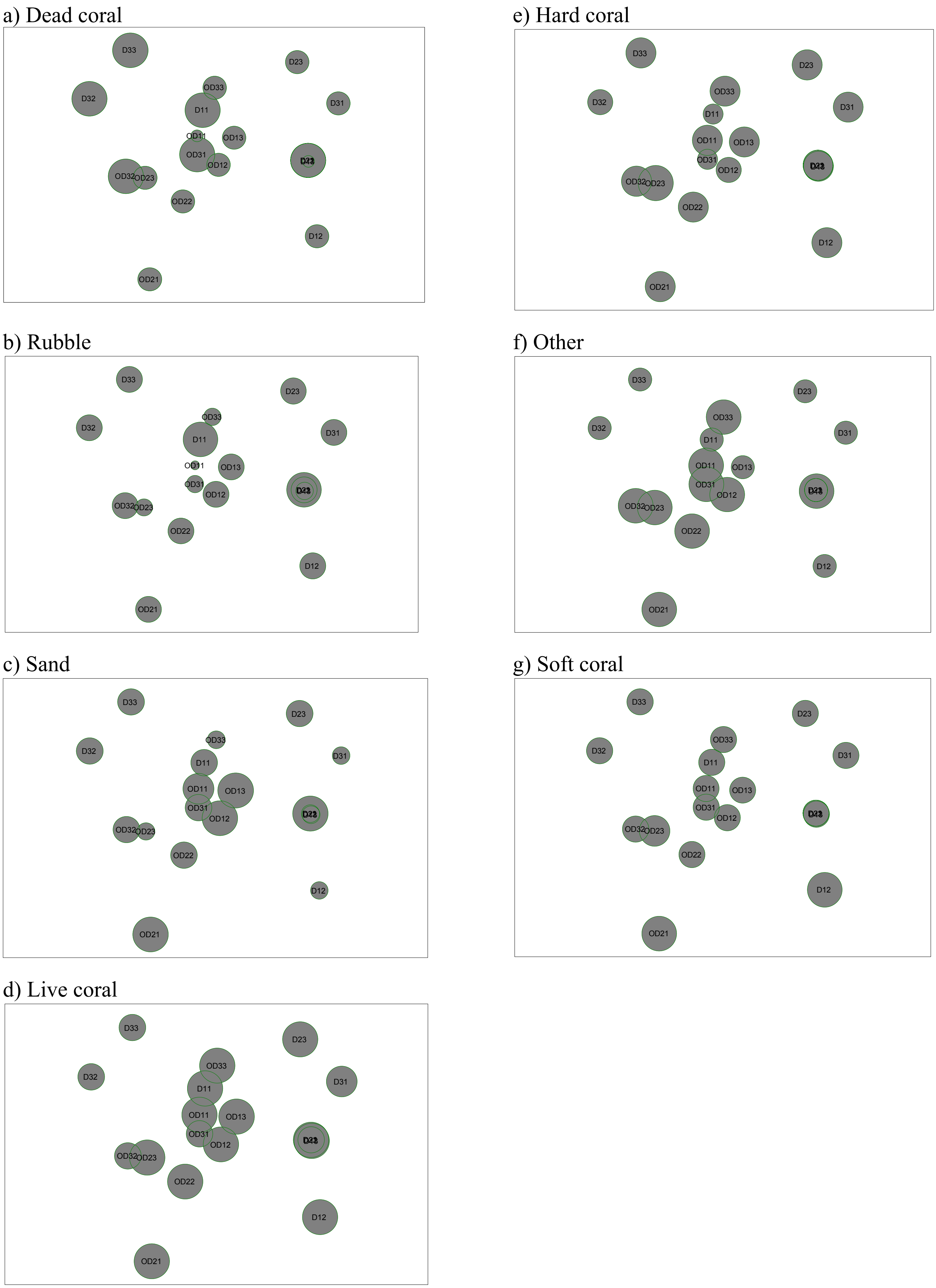

Fig. 5. MDS ordination plot as in Fig. 4. with covariate ranked substrate data overlayed with 'bubble' plots.

Comparison with Reef Check results

Comparison of results for fishes from this survey with those from Hodgson's (1999) global reef survey are shown in Figure 6, with the caveat that differences in sampling methods, and much smaller sample size for East Timor limit the comparability of the data. The finding of no Napolean Wrasse or Bumphead Parrotfish was consistent with those from Hodgson, who found Humphead Wrasse and Bumphead Parrotfish absent from 86% and 67% of sites in the Indo-Pacific respectively. Only one lobster was observed during this study, which is also consistent with Hodgson's finding of no lobsters at 85% of reefs surveyed. As shown in Figure 6, this East Timor study had more sites with high abundance classes for snappers, and groupers than the global reef survey, with the opposite true for sweetlips and parrotfish.

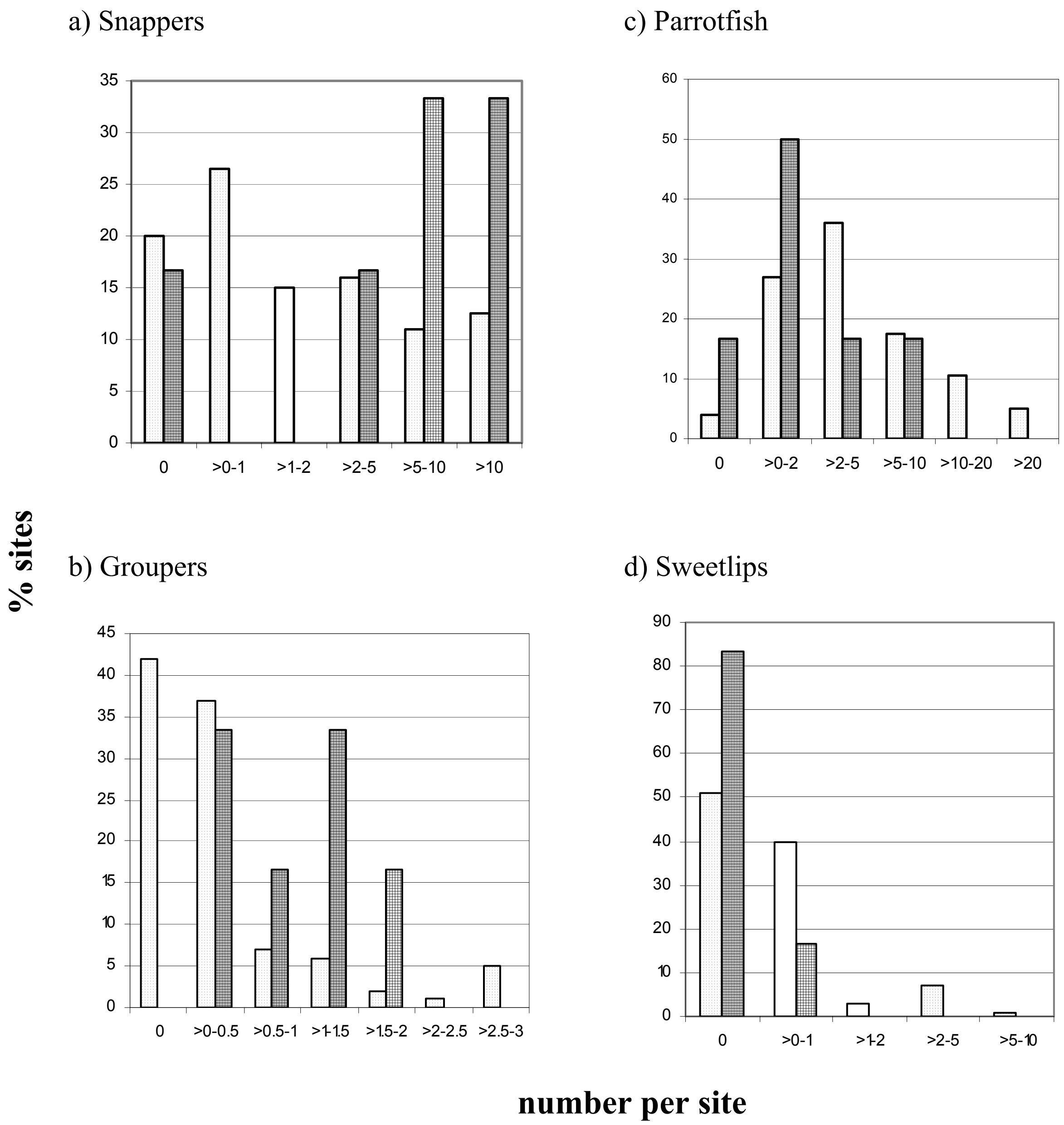

Fig. 6. Comparison of frequency distribution of sites among abundance classes for a) snappers, b) groupers, c) parrotfish and d) sweetlips between Indo-Pacific data from Hodgson's (1999) global reef survey and this East Timor survey. ⊡ Hodgson 1999 data ⊞ East Timor survey data.

Discussion

Fishing impacts observed

The results of this study provide evidence that fishing pressure has led to detectable changes in fish abundance in East Timor's coal reefs. Lower median family richness, lower mean number of snapper and lower median number of parrotfish for Dili sites indicate that fishing is impacting on fish abundance, thereby refuting the null hypothesis of no difference in fish abundance between locations. These results are likely to have biological significance, as according to Samoily and Carlos (2000), the low power of point count methods mean that for a moderate number of replicates, only fairly large differences in density (e.g. at least 50%) are detected.

However, some support was provided for the null hypothesis, as for groupers no significant difference was found between locations. The findings for groupers in this study are somewhat unexpected. Numerous studies have shown that fishing can significantly affect the density, biomass and average size of large predatory fish on coral reefs (Russ & Alcala 1998). Groupers are among the top predators on coral reefs, and tend to be k-strategists, demonstrating slow growth, late reproduction, large size and long life-spans which render them vulnerable to overexploitation (Morris *et al.* 2000). However, groupers tend to be secretive and are strongly associated with habitat structure, occupying caves, crevices and ledges (Sluka *et al.* 2001). Some groupers may have been overlooked, as UVC methods tend to underestimate abundance of cryptic reef species (Schmidtt *et al.* 2002). However, such underestimations should have affected both locations equally. The covaritate data recorded by this study were inadequate to capture any habitat differences that may have related to grouper abundance, such as availability of shelter holes and structural complexity (Munday 2002). Such data would have been useful, as they may have helped to explain the significant variability in mean number of groupers (all groupers, and groupers <30cm) between sites.

Very few parrotfish were recorded during this survey. In contrast to this, Gust *et al.* (2001) cite a study by Meekham and Choat (1997) which reports that parrotfish display particularly high local densities. According to Gust *et al.* (2001), UVC techniques can provide reliable measures of parrotfish distribution and abundance. The results of this study therefore indicate that parrotfish abundance may have been substantially reduced by fishing. In support of this, Russ and Alcala (1998) report that a range of studies have documented strong fishing effects on parrotfish, while in contrast, their own study found only weak fishing effects on parrotfish.

Very few sweetlips were recorded during the survey. However, sweetlips are typically inactive during the day, sheltering near or under ledges (Lieske & Myers 1994), which may have limited observations during this study. However, searches for cryptic fish were undertaken, and no sweetlips were observed during such searches, while a number of groupers were observed sheltering under ledges. The results for snappers were not unexpected, as they have been found to be strongly vulnerable to overfishing (Russ & Alcala 1998).

Limitations of study methods

There were a number of limitations to the methods of this study. Firstly, effects of fishing on abundance of individual species may differ from that on whole families, so that the study was attempting to assess effects of exploitation at a rather coarse level (Russ & Alcala 1998). The study was also limited by difficulties identifying fish. For example, one snapper species was not identified until partway through the study, and so was not included in the study. Estimated data including this species resulted in an even more significant difference for snappers between locations ($F_{1,12}$=19.73, P=0.008). Some other species belonging to target families may also have been missed. Fish size tends to be overestimated with UVC methods (Schmitt *et al.* 2002). Use of a 30 cm reference stick aimed to help prevent this.

There are many variables that may affect fish behaviour, including time of day and tide (Samoilys & Carlos 2000). While it would have been ideal to randomise the order in which the sites were sampled to account for such variations, time and transport constraints made it preferable to survey nearby study sites consecutively. To provide some standardisation, where possible this study was undertaken during the middle of the day, when fish are expected to be most active (Santos *et al.* 2002). However, sampling constraints limited this to some extent as discussed previously.

Ranking of covariate data provided only a coarse indication of habitat quality. More detailed habitat information (as discussed above for groupers) with more specific measurements may have provided more useful information. Detection function was not calculated prior to undertaking this survey. For the sites outside Dili, visibility was better than for the Dili sites, and this may have biased results. For both sites, however, visibility was adequate for fish at the edge of the count area to be identified. A limitation of this study is that only one depth was sampled. Stratified sampling, including more than one depth would have been preferable.

The precision (D) of data was assessed as per Elliot (1977). All data, except those for parrotfish <20 cm (D=0.73) were found to have D between 0.22 and 0.4, within reasonable range of conventionally acceptable error of 20% of the mean (A. Boulton 2003, pers. comm., 31 May).

Reef structure

Covariate data indicate that the reefs sampled had similar structural features with good structural integrity. Rubble and dead coral are associated with dynamite fishing. The finding of slightly more dead coral and rubble associated with Dili sites and slightly live coral and hard coral associated with outside Dili sites indicate slightly higher anthropogenic impacts (dynamite fishing) in Dili compared to outside Dili.

Condition of East Timor's reefs in a world context

The comparability of data from this study to the global reef survey is limited by differences in survey methods. The global reef survey undertook stratified sampling at depths of three and 10 metres, using four 20 m long transects per site, with counts undertaken for three minutes at five metre intervals. In contrast, this study used only three 10 minute point counts per site. Clearly, fish numbers should be lower for the East Timor survey, due to smaller sample area. The observed higher abundances of snappers, and groupers for East Timor can therefore be cautiously interpreted as better than average for the Indo-Pacific. The finding of comparatively low numbers of parrotfish and sweetlips in East Timor can be treated as indicative only. Observations from this survey of only one lobster and no humphead wrasse and bumphead parrot fish are consistent with low numbers found by the global reef survey at other reefs in the Indo-Pacific.

Hodgson's (1999) global reef study led to the conclusion that there is a serious global crisis facing coral reefs. It was predicted prior to undertaking this survey, that East Timor's reefs would be in particularly good condition due to limited commercial exploitation. It is clearly not possible to conclude whether East Timor's reefs are in particularly good condition, although the comparison indicates that this is unlikely to be the case. This highlights the need for further research to be undertaken in East Timor.

Conclusions

In conclusion, the results of this study provide evidence that overfishing is impacting on fish assemblages in East Timor. Long term studies/monitoring are urgently required to further understand the stability of populations of fishes in East Timor's fringing reefs. Such studies could help determine whether or not fishery resources are threatened by the level of fishing they are subjected to through verification of spatial patterns observed in this study, and monitoring changes in fish community structures and fishing intensity through time.

There is an increasing body of evidence that no-take reserves increase fish abundance, and may increase fish catch in adjacent fished areas (Galal *et al.* 2002). The results of this study indicate that it is imperative for some MPAs to be established in East Timor.

Acknowledgements

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