Fishing Controls, Habitat Protection and Reef Fish Conservation in Aceh

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ABSTRACT

In 2006 and 2007 we conducted coral reef and socio-economic surveys in the northern Sumatra islands of Weh and Aceh, to evaluate existing fisheries management practices and the influence of management on coral reefs. Two types of marine resource management were found to exist on Weh Island. A community management system known as the Panglima Laot was being implemented in at least one region of the island and a government tourism reserve or Kawasan Wisata was in place in another region. Both areas had prohibited the use of netting for reef fish over the past 10 years. Areas open to unregulated fishing, except for prohibitions on blast fishing and use of cyanide, also exist on Weh island and a group of islands to the west known as Aceh. In April 2006 and 2007 we examined the structure of coral reef fish populations in each of these 4 areas, the Panglima Laot and Kawasan Wisata and the open access areas of Weh and Aceh islands. The overall biomass of reef fish was greater in marine managed areas than in unmanaged areas but did not differ between years. A separation was also found in the trophic structure of reef fish between managed and unmanaged areas. In managed areas, where cover and diversity of corals was highest, coral dependant reef fish (eg. Chaetodontidae, Pomacentridae) had higher biomass than in unmanaged areas. For fish that are targeted by local fisheries, both carnivorous and herbivorous species showed no difference in biomass among the management areas but both Labrids and omnivores had greater biomass in managed areas where netting was prohibited. The trends indicate a positive influence of management controls on the biomass of some trophic groups. Higher biomass of small size class fish (5-15 cm) were found in the managed areas compared with unmanaged areas, and as such recruitment of fishes is possibly more successful within these areas. Although it is clear that habitat and food availability regulate fish biomass and structure, the prohibition of netting practices and relatively low fishing pressure in managed areas may explain some of the differences in the structure of reef fish between managed and unmanaged areas. Reductions in destructive fishing that occurred in some places years before the introduction of regulations on netting also protected some coral habitats from damage and is likely to have contributed to differences in reef fish population structure. These data together with information on critical habitats, socio-economic conditions and stakeholder perspectives are being used to design a network of marine protected areas for the region.

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INTRODUCTION

In response to worldwide degradation and collapse of marine resources a growing interest toward more effective management in marine resources is occurring (Dayton et al. 1998, Friedlander et al. 2003). Management agencies are applying concepts of marine resource protection by recommending and implementing marine protected areas that include a variety of regulations aimed at reducing negative impacts from human and natural causes. These areas form an important component of marine conservation whereby certain areas are off limits to extraction of marine resources and provide long term stability of marine ecosystems. They can also halt the decline in marine biodiversity and changes in species and functional groups of marine taxa. The adoption of marine protected areas is a precautionary approach to management that reduces the effects of exploitation and applies an ecosystem based approach to allow ecosystems to function naturally and provide fisheries enhancements. The design and expansion of marine protected areas (MPA's) in response to the continued exploitation of marine resources is considered a necessary management tool for protection of fish populations (Sladek Nowlis and Roberts 1999, Halpern 2003, Sale et al. 2005) and for areas of biodiversity and ecosystem function (Bellwood et al. 2004).

On coral reefs, the intensity and frequency of overfishing contributes to extreme spatial and temporal variability in the biological structure of shallow-water marine communities (Karlson and Hurd 1993, Hughes and Connell 1999). In the extreme, synergistic effects of multiple chronic disturbances such as over-fishing and nutrient inputs can lead to irreversible and fundamental shifts in biological structure from coral-dominated to algal-dominated benthos (McCook, 1999). This in turn may have significant repercussions for the long-term survival of coral associated reef fishes (Wilson et al., 2006). The benefits of MPA protection in providing increased fish stocks and other improvements in resources have been reported globally (Russ 2002) and MPAs are also advocated widely as a management tool to conserve reefs in Indonesia (Mous et al. 2005). Yet although coastal marine habitats in Indonesia have been subject to a long -history of disturbance from destructive fishing practices (Tomascik et al. 1997, Edinger et al., 1998, Pet-Soede et al. 1999) few reports describe ecological benefits that have been attributed directly to MPAs in Indonesia (Christie 2004, McClanahan et al. 2006, Campbell et al. 2007). Such paucity of data in Indonesian MPAs can be attributed to lack of implementation of MPA regulations and lack of enforcement within these areas.

Coral reef fish populations are highly variable in space and time as they exhibit high movement, diel changes, migrations, high spatial variability with changes in habitats. and observer biases. This inherent and near-instant variation in coral reef fish communities makes it difficult to detect temporal changes in these communities and to attribute changes to a given anthropogenic stress. It is therefore important to measure features of reef fish communities that are capable of showing change over relatively long time scales. This may be possible for a few species, yet pooled or aggregated community metrics such as species numbers or densities and biomass at the family, community and functional level have greater potential for detecting change at the sample sizes possible in coral reef studies (McClanahan et al. 2007a).

Coral reefs in northern Aceh gained prominence following the 2004 tsunami where initial reports of widespread damage were grossly unfounded (Baird et al. 2005). It was shown that past management and the misuse of coral reefs was likely to have been the dominant factor structuring coral reef communities (Campbell et al. 2007). Coral reefs of Aceh have been subject to destructive fishing practices, such as cyanide fishing and bombing, over many years with devastating effects on fish stocks as well as the benthic reef habitats. Yet existing conservation management practices have largely been unreported. In this study we examined the status of coral reef communities

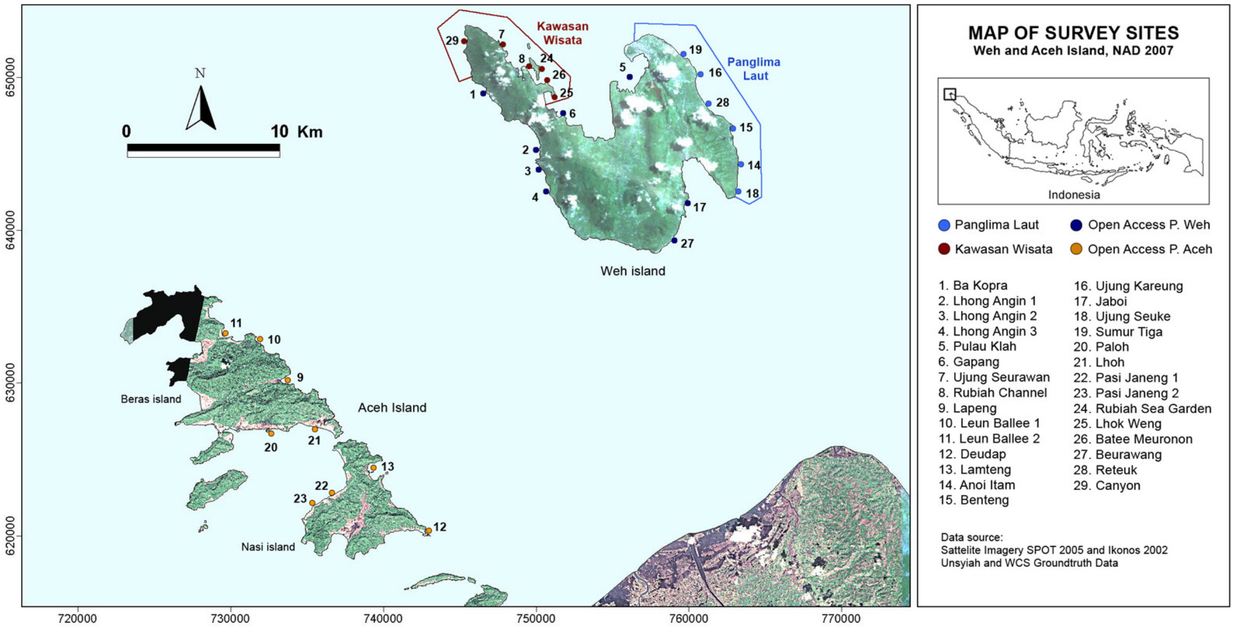

Figure 1. Location of reef fish survey sites in Aceh during 2006 and 2007 surveys.

(both coral and fish communities) inside and outside marine managed areas in Aceh, against a background of considerable prior disturbance from destructive fishing practices. To evaluate if current management practices were working in Aceh we surveyed 29 sites located within 4 management areas; a government gazetted tourism conservation area (Kawasan Wisata) (6 sites), a traditional Achenese management area (Panglima Laot) (6 sites) and inside unmanaged areas with open access to fishing on Pulau Weh island (8 sites) and Pulau Aceh islands (9 sites) with open access to fishing (Fig. 1). In both managed areas regulations prohibiting the use of nets and other destructive practices had been enforced for 10 years while fishing with lines, spears, traps and other artisanal gears occurred. In open access areas fishing was unrestricted and reports of destructive fishing practices from 1970 through to the late 1990's were common. We also examine the level of community compliance and existing fishing effort with existing marine resource regulations.

METHODS

Reefs of Weh and Aceh islands situated off the northern coast of Sumatra, Indonesia for the most part grow on bedrock and in unconsolidated sediments. Reefs surround the islands and are subject to prevailing winds and currents dependant on geographic location and season. A selection of sites that represented the diversity and geography of coral reefs of the region were surveyed in April 2006 (27 sites) and February 2007 (29 sites). The objective was to examine the structure of coral reef fish assemblages within replicate sites inside marine managed areas at 2 locations and outside managed areas at 2 locations. The areas included a government managed tourism conservation area (Kawasan Wisata) (207 ha) (6 sites), a traditional Achenese management area (Panglima Laot) (206 ha) (6 sites) and outside managed areas (>1000 ha) on Pulau Weh island (8 sites) and Pulau Aceh islands (9 sites) (Fig. 1).

Estimates of Coral Abundance

Coral cover was estimated at each site using three 50m transects, and at each 0.5 m interval the scleractinian coral genus under the transect was recorded. Two of these transects were the same as transects used to estimate fish abundance. Cover was then expressed as the number of times a coral genus was recorded along a transect divided by the total number of intercept points (n=100) per transect.

Estimates of Fish Abundance

Visual estimates of reef fish species abundance and size at each site was measured at a depth of 0-2 m and 6-8m along three 50m x 5m belt transects per depth in April 2006 and February 2007. All fish were recorded from a total of 41 families except for sediment dwelling families Gobidae, Blenidae and Tripterigidae. Surveys were conducted during daytime to reduce possible temporal effects on fish abundance among sites. Fish were visually assigned to one of 9 size classes (<5 cm, 5-10cm, 10-15 cm, 15-20 cm, 20-25 cm, 25-30 cm, 30-35 cm, 35-40 cm and >40 cm). Fish less than 10cm and those greater than 10cm were surveyed separately on the same transects. Abundance was expressed as the mean abundance of fish per hectare.

Fishing Intensity

To obtain a standard measure of fishing effort within each management area (except in open access Aceh island where data was not available) the mean number of fishing trips per fisher within 7 lhoks (sub-district) in each management area (identified from household surveys of 143 fishers) was multiplied by the total number of fishers who fished on coral reefs in the lhok and divided by reef area adjacent to each of the lhoks.

Statistical Analyses

Using two-way analysis of variance (ANOVA) we examined the effect of management areas (fixed; 4 levels, Panglima Laot, Kawasan Wisata, open access Pulau Aceh, open access Pulau Weh) and time (fixed; 2 levels, 2006 and 2007) on mean fish biomass, mean biomass of 6 trophic groups at each site, mean biomass of 6 major fish families at each site, mean biomass of 9 size classes of all reef fish pooled and mean coral cover at each site (random; 6 - 9 levels). In order to understand if the variation in reef fish biomass was highest between sites within management areas (among sites) or among management areas we performed separate analyses for each year using nested ANOVA. For these analyses reef fish biomass data from each transect (n = 6) at each site (random; 6 - 9 levels) were nested within each management area (fixed; 4 levels). Significance among factors was tested at the $p<0.05$ level.

RESULTS

Reef Fish Biomass

The mean biomass of reef fishes in 2006 and 2007 (averaged across all families) varied by an order of magnitude among sites. In 2006 the mean (± standard error) biomass ranged from 118.2± 72.3 kg ha-1 at Pasi Janeng (site 23), up to 1193.7± 332.2 kg ha-1 at Ujung Kaureung (site 16). In 2007, biomass ranged from 149.2± 49.2 kg ha-1 at Lapeng (site 9), up to 1561.9± 554.8) kg ha-1 at the Canyon (site 29) (Fig. 2). The families with the highest biomass were the Pomacentridae and Acanthuridae which accounted for 17% and 14% of all fishes counted respectively. The next most abundant families of fishes were the Scaridae, Chaetodontidae, Labridae and Pomacanthidae, although families comprising mostly small or cryptic fishes (e.g., Apogonidae or Blennidae), which comprise a significant component of the ichthyofauna on coral reefs (Munday and Jones 1998), were not surveyed.

Nested ANOVA (site (management area)) were performed to examine variation in reef fish biomass among sites within management areas and among management areas, separately for 2006 and 2007. In this case an effect of management was found in 2006 (df 3,20, $F=7.310$, $P<0.002$) and 2007 (df 3,22, $F=3.378$, $P<0.038$) suggesting that management had an influence on reef fish biomass. Significant variation among sites nested within management zones, in 2006 (df 22,148, $F = 2.746$, $P < 0.001$) and 2007 (df 20,84, $F = 2.216$, $P = 0.006$) was also found indicating high

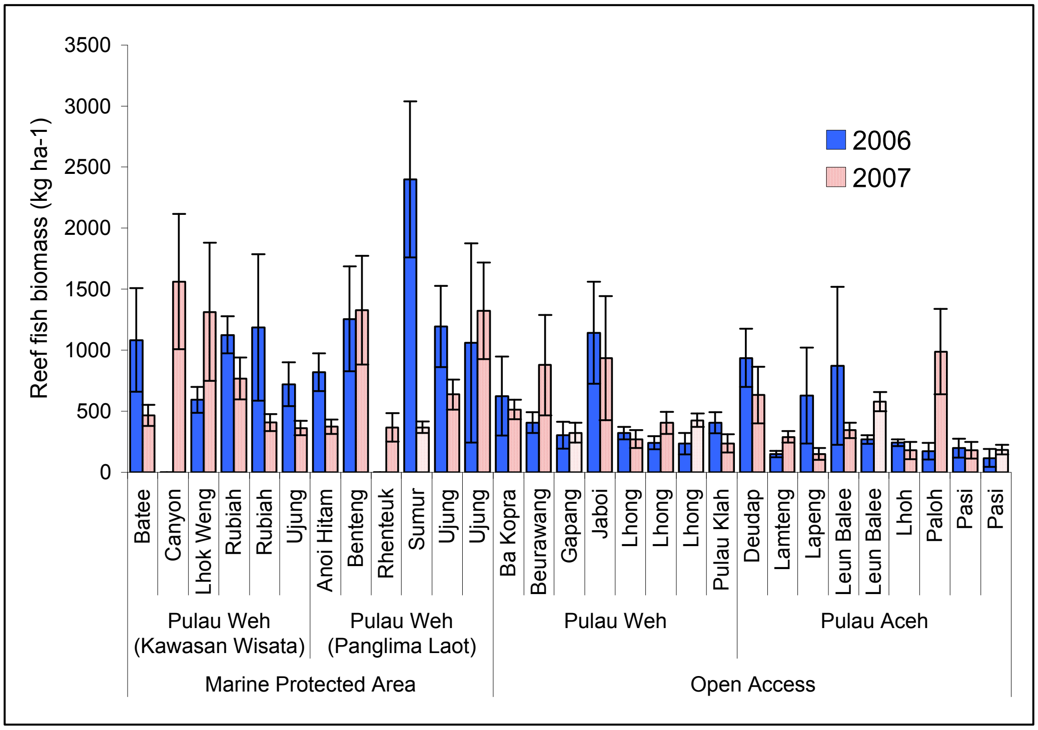

Figure 2. Mean (±Standard Error) reef fish biomass (kg ha^{-1}) of all fish species at 29 sites in 4 management areas of Aceh in 2006 and 2007.

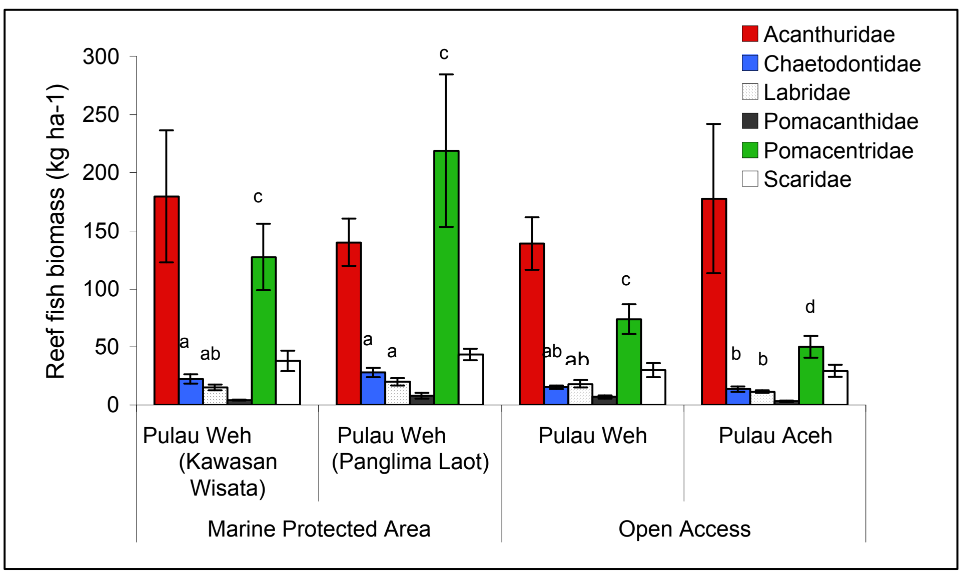

Figure 3. Mean (±Standard Error) reef fish biomass (kg ha^{-1}) of six major families in 4 management areas of Aceh in 2007. Different superscript letters denote significant differences ($P<0.05$) in biomass among management zones for a given reef fish family.

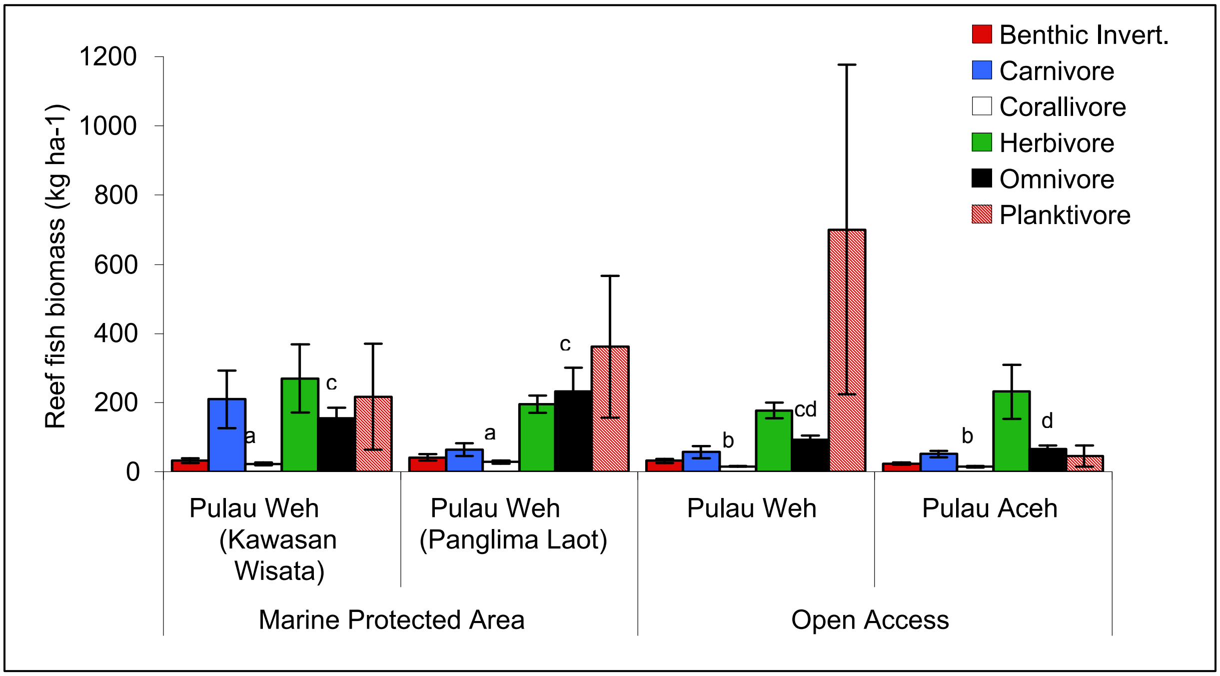

Figure 4. Mean (±Standard Error) reef fish biomass (kg ha^{-1}) of trophic groups in 4 management areas of Aceh in 2007. Different superscript letters denote significant differences (P<0.05) in biomass among management zones for a given reef fish trophic group.

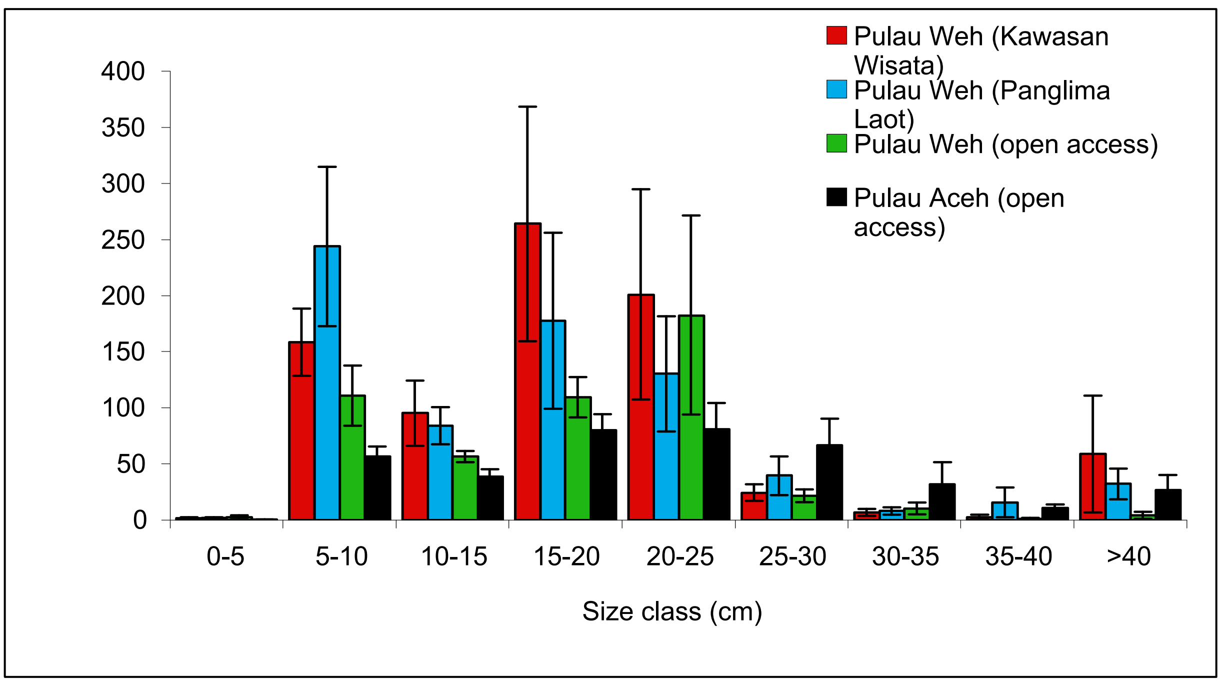

Figure 5. Mean (±Standard Error) reef fish biomass (kg ha^{-1}) of size classes in 4 management areas of Aceh in 2007.

variation in reef fish biomass among sites within a given management area.

Reef Fish Structure

At sites within the Kawasan Wisata and Panglima Laot on Weh island there was higher biomass of Chaetodontidae, Labridae and Pomacentridae compared with open access areas of Pulau Aceh (Fig. 3). This was also reflected in the trophic structure with higher biomass of corallivores (mostly Chaetodontidae) and omnivores (mostly Balistidae and Pomacentridae) in Kawasan Wisata and Panglima Laot areas compared with open access areas of Pulau Aceh (Fig. 4). The size structure of coral reef fish assemblages was characterized by a higher biomass of 5-10 cm, 10-15 cm and 15-20 cm size classes in Kawasan Wisata and Panglima Laot compared with the open access area of Pulau Aceh (Fig. 5).

Coral Cover

There was a significant effect of management area (df 3,48, $F = 22.273$, $P < 0.001$) on percentage coral cover with post-hoc tests (Bonferoni) revealing significantly lower coral cover in open access Pulau Aceh (9.16 ± 1.50) compared to open access Pulau Weh (26.0 ± 2.21), Kawasan Wisata (38.8 ± 2.67) and Panglima Laot (53.3 ± 2.82) areas. Coral cover in the Panglima Laot area was also significantly higher than in the open access area of Pulau Weh.

Fishing Pressure

Highest fishing pressure was found in the lhoks of Balohan and Keunekai within open access areas and lowest in marine protected areas in Panglima Laot and Kawasan Wisata lhoks (Fig. 6).

DISCUSSION

Teasing apart the effects of habitat condition and management regulations on reef fish populations is difficult given the complex associations between low coral cover, low fish densities and high fishing

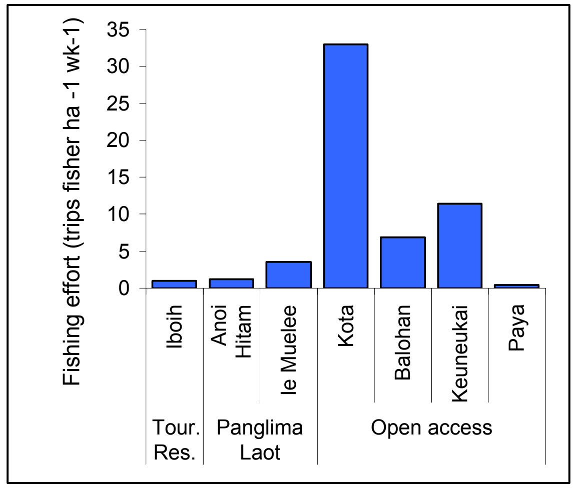

Figure 6. Mean fishing effort (trips $fisher^{-1}$ ha^{-1} wk^{-1}) at seven lhoks (sub-districts) and 3 management areas of Pulau Weh in 2006.

pressure and the influence of coral habitat type and area on coral reef fish assemblages (Russ and Alcalca 1996, Bellwood and Hughes 2001). Nonetheless, the lower fish abundance in open access fishing areas of both Aceh and Weh, irrespective of the lower coral cover and diversity, suggests that past fishing practices, including bombing and cyanide poisoning that were common throughout Indonesia (Pet Soede et al. 1999, Tomascik et al. 1997, Hopley and Suharsono 2002) impacted coral cover and fish biomass in Aceh. Because of the national laws prohibiting these illegal practices it is unlikely that fishers will admit to their use. In contrast, local management regulations such as bans of netting are rarely enforced so information from fishers on their use of legal gears are likely to reflect accurate estimates of fishing pressure. The relatively lower fishing pressure inside marine protected areas compared with areas where fishing is unregulated has almost certainly benefited reef fish biomass, despite regulations limiting netting not being fully complied with, enforced or monitored. Alternative income opportunities (ie. tourism, agriculture) in the lhoks adjacent to the marine protected areas have more than likely reduced dependency on fishing in these areas and allowed communities to comply to some degree with fishing regulations.

The enhancement of fish numbers inside marine protected areas is likely to be closely coupled with habitat availability which promotes growth and maturation of fish in post-recruitment phases (Jones and McCormick 2002). Coral dwelling species including Pomacentridae, Chaetodontidae and Labridae showed higher biomass in protected areas where coral cover and diversity was higher than in open access areas (see also Baird et al. 2005). Both Pomacentridae and Chaetodontidae are heavily reliant on coral habitat (Bellwood and Hughes 2001, Jones et al. 2004) which provide shelter from predatory fish species and are likely to improve survival (Jones and McCormick 2002). Coral habitat is also likely to assist in recruitment of reef fishes by providing cues for active habitat selection by reef fish larvae (Montgomery et al. 2001). These coral dwelling families are not targeted by fishing and hence differences in biomass would appear directly related to the quality and quantity of coral habitat.

In Aceh, the first 10 years of marine management has seen Labrids and the faster growing coral dwelling Chaetodontids and Pomacentrids benefit in terms of biomass from the marine management in place, as they are clearly disadvantaged in areas where coral cover and diversity is low and algal growth is high. In contrast families such as Acanthuridae, Scaridae and Pomacanthidae showed no differences in biomass between protected and non-protected areas although both Acanthuridae and Scaridae are targeted by net and handline fisheries. This suggests that the trophic behaviour of reef fish may to some extent explain the observed differences in biomass among management areas. Both Acanthuridae and Scaridae are roaming herbivores that may be supported by high abundance of algae typically found in the open access reefs of Aceh and Weh (Campbell et al. 2007). Ecological succession may also explain differences in reef fish structure as increases in the biomass of some families such as Labridae and Scaridae have been reported during the first ten years of closure from fishing, while increases in the biomass of Balistids and Acanthurids have taken 10-20 years of closure (McClanahan et al. 2007b). In coral reef systems fish biomass may take many years or decades to recover to full diversity and biomass (Micheli et al. 2004, McClanahan et al. 2007b), as the influence of competitive interactions among functional groups alters the rate of change in the biomass of reef fish with time.

The paucity of small fish size classes (5-15 cm) in open access areas of Weh and Aceh islands may be due to the overuse of nets in open access areas and capture of small size fish. However, our observations suggest that exploitation of small sized fish is not a major concern except possibly the targeting in some areas by the reef fish aquarium trade. Interestingly we have noted large numbers of small sized cohorts in both 2006 and 2007 fish surveys in marine protected areas suggesting that recruitment to these reefs may be occurring. Mechanisms responsible for possible recruitment remain unclear although factors linked to habitat availability that affect recruitment and predation, including density dependent post-settlement mortality, food supply, larval growth and larval mortality (Jones and McCormick 2002), may influence reef fish structure in Aceh.

The overall higher reef fish biomass and low fishing effort in protected compared with open access areas, indicates a degree of compliance with fishing regulations and a sensitivity of reef fish populations to community or district based management controls. Yet the low biomass of carnivorous fish found in all management zones indicates that these populations remain in a state of severe depletion. Although fishing effort is low in protected areas and restrictions on netting may be working, a lack of restrictions on handline and speargun fishing and the illegal use of cyanide to target carnivores has undoubtedly contributed to the depletion in large fishes, typical of overfishing in coral reef systems (Russ and Alcalca 1996, Micheli et al. 2004). Controls such as gear restrictions and periodic closures may be popular with local communities but have limits to preserving fishery dependent species and ecological processes. On the other hand, permanent closures have been advocated as the only way to maintain coral reef ecosystems that are representative of unfished ecosystems with high fish biomass (McClanahan and Graham 2005, McClanahan et al. 2007b). Achieving this in Aceh is problematic when fishing dependency is often seasonally high, enforcement of regulations is low, limited monitoring occurs and poor management among responsible agencies persists.

In the absence of data on reef fish populations prior to restrictions on fishing we cannot conclusively attribute the higher biomass of reef fish in the Kawasan Wisata and Panglima Laot protected areas to regulations limiting netting in these areas. The differences may also be due to the history of blast fishing which ceased in the late 1980's in the two managed areas of Pulau Weh but continued unabated until the mid 1990's in some of the open access areas. Nonetheless, whether it be gear restrictions. limiting fishing pressure or the reduction in destructive fishing the conservation practices adhered to by communities would appear to have benefited coral reefs by reducing the harvest of some species of reef fish and protecting coral from damage. Responses of fishes to protection from fishing are influenced by many complex factors, including the size of reef, the structure of reef fish populations, the proximity of other reefs and the level of compliance with protection regulations (Babcock et al. 1999; McClanahan and Mangi 2001; Shears and Babcock 2003) and positive effects of protection may require many years to become manifest (Micheli et al. 2004, Russ et al. 2005, McClanahan et al. 2007b). Nonetheless, local MPAs such as the ones studied in the present study are gaining increasing acceptance among scientists as one of the few effective ways of managing fisheries of coral reef species (Russ 2002), and may be critical in making reefs more resilient to acute natural and anthropogenic disturbances (Bellwood et al. 2004).

The coral reefs of Weh Island more than a year after the tsunami are largely intact. The legacy of traditional and government based marine resource management appears to have protected some reefs from human misuse and afforded refuge for a diverse and abundant suite of reef fish. These reefs have depleted numbers of species targeted by artisanal coral reef fisheries most likely because permanent closures or no take zones have not been part of the management controls in Aceh and continue to lack community support. Nonetheless, the findings of existing community or government based management in reducing unsustainable fishing practices on coral reefs have rarely been documented in Indonesia (Christie 2004, McClanahan et al. 2006). On Aceh Island the condition of many reefs remains a cause for concern, yet the chronic mismanagement of marine resources appears to have abated in the wake of the tsunami and there is evidence that recruitment of corals and fish is occurring. This encouraging response is evidence of the resilience of coral reefs to severe disturbance and the determination of local communities to protect some of the most diverse coral reefs in Sumatra over the past 10 years. Pivotal to achieving sustainable fisheries and coastal livelihoods will be the strengthening of relationships between the communities and institutions involved in marine resource management.

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