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DIVERSITY OF REEF FISH FUNGSIONAL GROUPS IN TERMS OF CORAL REEF RESILIENCES

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ABSTARCT

Infrastructure development in the particular sites of Seribu Islands as well as those in main land of Jakarta City increased with coastal population this phenomenon is likely to increase the effects to the adjacent coral waters of Seribu Islands. Chemical pollutants, sedimentation, and domestic wastes are the common impact and threatening, the survival of coral reef ecosystem. Coral reef resiliences naturaly remained on their processes under many influences of supporting factors. One of the major factor is the role of reef fish functional groups on controling algae growth to recolonize coral juveniles. The aim of this study to obtain data of a herbivory and other fish functional groups of reef fishes in the Pari Islands that are resilience indicators, or that may indicate the effectiveness of management actions. A conventional scientific approach on fish diversity and abundance data gathering was conducted by the underwater visual cencus. Diversity values of the reef fish functional groups, such as the abundance of individual fish including species, were collected and tabulated by classes and weighted as a baseline to understand the resilience of coral reed based on Obura and Grimsditch (2009) techniques. The results succesfully identified several fish functional groups such as harbivores (21 species), carnivores (13 species) and fish indicator (5 species) occurred in the area. Regarding the aspects of fish density and its diversity, especially herbivorous fish functional group, were presumably in the state of rarely available to support the coral reef resiliences. Resilience indices ranged from 1 (low level) to 3 (moderate level) and averages of the quality levels ranged from 227 to 674. These levels were inadequate to support coral reef recolonization.

Keywords: Resiliences; reef fishes; Pari Islands

INTRODUCTION

Coral reefs were known as fish habitats where some ecological niches exist to support various fish functions in coral reef ecosystem. Some functions will collapse in damaged coral reefs due to lost of ecological niches (Jones *et al*., 2004). Such as in unfavourable circumstances of the coral reefs, there are some losses of reef fish species and others remain to survive occupying the areas due to adapting capability. Unhealthy habitat conditions commonly derived from changes in coral covers and poor body waters as a result of sedimentation and run off from main land (Jones & Syms 1998).

Land based run off as an external factor could contribute a significant influence to community structures, functional composition of reef fishes and coral life (Mallela *et al*., 2007; Manthachitra & Cheevaporn, 2007). According to Amesbury (1981), there was a significantly relationship between abundance or diversity of reef fishes and water transparency that are depending on accumulative deposit of sedimentation transport by fluvial processes. Some studies were also indicated that there is significant relationship between reef fish abundance, spesies diversity and live coral coverages, which reef fishes considerable changed community structures and loss diversity particularly due to hard-coral cover dwendling. (Halford *et al*., 2004; Jones *et al*., 2004; Graham *et al*., 2006; Wilson *et al*., 2006).

Decreasing in enviromental quality has lead to negative impacts to Seribu Island coral reefs throughout the last three decades 2005 to 2007 surveyed generaly indicated that 4.2 % of coral covers were declined (Terangi, 2007). The negative impacts of development in Jakarta Bay likely and its adjacent waters likely produced substantial chemical pollutant, sediment, and domestic wastes (Suprapto *et al*.,

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2011). In addition, marine resort and property development in Tengah Island of Seribu Islands and massive coastal reclamation in the areas that directly influenced body water quality and generates poor impacts on status of local coral reef communities. All of the activities were predicted as local stressors for Pari reef areas, therefore it is needed to measure changes of fish community structures in this specific area.

Changes in bottom substrate may affect to the reef ecosystem services. Hence, it is important to monitor the coral reefs capacities that are be able to support intensely to reef fish communities in the Pari Islands. The changes may influence to community structures and then these changes will sequentially influence to nature of reef biota growth. Changes of coral cover take place due to settlement modification of reef fishes that have special functionsin food web as well as increasing in harbivorous reef fish families as a grazer group controling macroalgae growth for new recruitment of hard corals, or due to unfrendly fishing as well (Green & Belwood, 2009**)**. Grazing fishes have abilities to adjust substrates on coral reef by using positively or negatively ways. Fish habitat and fish communities may disturb each other and in turn lead to coral reef resilience depending on herbivorous reef fishes. In food web, carnivore fishes may control the herbivore fishes, and the other hand, fishing activities may reduce fish population, especialy carnivore group such as groupers, snappers, sweaplips (Obura & Grimsditch, 2009).

Resilience is the ability of a system to absorb or recover from disturbance and change, while maintaining its functions and services. For example a coral reef's ability is to recover from a bleaching event (Grimsditch & Salm, 2006). According to Obura & Grimsditch (2009), the resilience is not only take place under damaged coral reefs condition, but also naturaly takes place in vigorous-coral reefs. Reef fish communities have capability to maintain or modify coral structures for its be sustainability. One of critical resilience factors is fish species and functional diversity. For this reason, It is essential to recognize functional groups of fishes supporting resilience processes of coral reefs. Resilience assessments could help to provide an early warning of decreases of its important resilience drivers.

Recently, there are three available methods for assessing pre-disturbance coral reef resilience, i.e. Obura & Grimsditch (2009), Maynard *et al*. (2010), and Bachtiar *et al*. (2011). This study is a part of Obura & Grimsditch (2009) method that only put emphazes to a roles of fish functional groups, especially herbivorous fishes. Diversity, density, composition and sizes of the fishes are substantial quality indicators from which they could be used directely on readily avaibale collected data and those in part of assessment on coral reef resilience in order to make management priority in a reef area already damaged (Obura & Grimsditch, 2009; Thibaut *et al*., 2008; Hughes *et al*., 2007).

This study aimed to gather selected-resilience indicators, especially variables data on herbivores and other functional groups of fish that exert top-down control on phase shift dynamics on coral reefs.

MATERIALS AND METHODS

Field observation was carried out in very short observation on March 2015 at the waters of Pari Islands, Seribu Island District. The study is addressed to provide information on some parts of quantitative assessment of coral resiliences by using indicators of functional reef fish groups that play a role insupporting coral resilience.

Well known that in coral reef areas there are always specifically interaction or respond of benthic organism each other. In the specific interaction, quantitative sampling can be conducted for functional fish groups such as herbivores, carnivores and omnivores. This study is mostly focused on biological indicators, e.g. (1) numbers of fish, overal and by functional groups. (2) abundance/density of the fishes by functional groups and species. (3) composition of fish populations, families and by functional/trophic groups.

A method used for data gathering was standard underwater visual census (UVC) of fish by focusing on herbivore functional groups and including other functional groups of fish (English *et al*., 1994; Obura& Grimsditch. 2009).

The method focused on census fish at sufficient resolution to allow analysis of individual and by functional group. The level of detail is needed for different functional groups varies from species to family level. Study sites took place inpermanent belt transects (Appendix Figure 1). The cencus area is 70 x 5 m in frame. Fish numbers by species were visually noticed by using waterproof papers. Species identification was determined by referred to pictorial guide of Indonesian reef fishes (Kuiter & Tonozuka, 2001; Allen & Erdmann, 2012).

Data Analysis

The data were listed by kinds of respective fish functional groups that might be indicators for supporting resilience process. The functional groups are the role of fishes in food web, and herbivorous fishes were selected as an example listed in Appendix Table 1. Feeding habits of the herbivorous fishes were separated into four categories (Appendix Table 2) (Berkepile & Hay. 2008; Obura & Grimsditch., 2009).

Preference attending of fish functional groups, such as individual numbers and fish species, were tabulated in scales (rankings) and weighted as basis for resilience indicators that followed tabulation by Obura & Grimsditch (2009). The scale and weight depend on variables of the individual number of reef fish functional groups (adapted from Berkepile & Hay, 2008; Obura & Grimsditch, 2009), such as herbivore (excavator, scarapers dan grazer), predator (piscivores), indicator (coral obligate), and others (invertivore/grazers). The ranking in terms of a character of resilience indicesisa degree based on Obura & Grimsditch (2009) including level from very low (1) to very high (5). The indices are derivedfrom interval individual numbers of a fish functional group. The weightwere calculated from cross over between a ranking (1 to 5) and an individual number of fish fungsional groups. According to Obura & Grimsditch (2009), the more increase in a weight value, the higher a functional group infuenced on resilience effects.

RESULTS AND DISCUSSION

Results

Finding of underwater visual cencus at three of transect sites of 21 fish species of major functional groups (herbivores) likely played a role on coral reef resiliences, especially, the fish species that are belong to families of Scaridae, Acanthuridae, Siganidae, Pomacanthidae and Kyphosidae. Figure 1 illustrates percentages of the respectively attending families as mention above. The figure shows that Scaridae was the most assertive family as well as *Scarus gobban* representatively attended in the largest number. All of the fish species found during visual cencus can be seen on the Appendix Table 1. Functional groups such as excavators, scarapers, grazers, browsers, which the species have already described by Obura & Grimsditch (2009),were variably found at the 1st and 3rd station of study siteswhere there were 17 species, respectevely; however at 2nd station was only found 2 species of scraper and grazer groups.

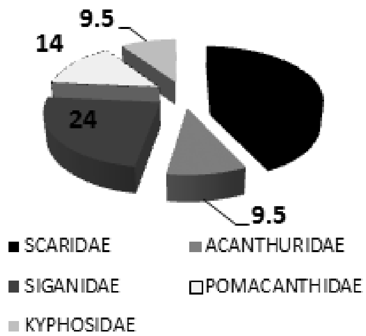

Figure 1. Major family composition (%) of harbivorous species identified in the three transect sites at the Pari Islands coral reefs.

The other functional groups that were also considered playing roles in coral resiliences consisted of 13 families (Figure 3), especially those were dominated in all stations by Pomacentridae (*grazers*) and Labridae (*invertivores*), the well known families have a usual great number and strong affinity to coral reefs (Appendix Table 4). Major pradator groups were represented by attending families such as rock cods (Serranidae), snappers (Lutjanidae), emperors (Lethrinidae), trevally (Carangidae), goatfishes (Mullidae), spinecheeks (Nemipteridae), sweetlips (Haemulidae), and squirrelfishes (Holocentridae). Some dominant predators families generally found at the 1st station1 and 3rd station of cencus areas included spinecheeks (5 species), snappers (4 species), and rock cods (4 species), however the 2nd station have lower deversityfor predator. In generaly, predator group attended under 5 % for which the persentage composition ilustrates on Figure 2.

An indicator functional group, the coral obligate of Chaetodontidae, was found in lower level. The coral obligates consisted of 5 species for respective transect sites of the 1stand 3rd stations, while those in the 2nd station were found to 1 species only. Their composition was only around 5% of total attending of the other functional species (Figure 2).

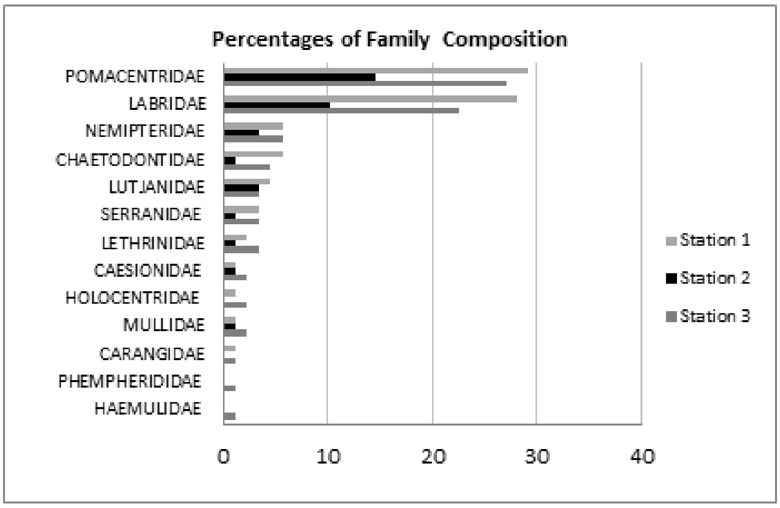

Figure 2. Family group composition of reef fishes indetified in three transect sites at the Pari Islands coral reefs.

Data analysis for grouping the reef fishes functions shows that there were four factors controled on coral resiliences and ranged from the high level to low level of intensities (Obura & Grimsditch, 2009), especially the factors derived from existences of herbivores, predators, indicators and other functional groups (Table 1). In both of the 1st and 3nd stations, the herbivory influences of an excavator entity included in low level, even those felt to be non effect in 2nd station. The Scrapers entity is moderately effected in the 1st station, lowly effected in the 2nd station and higly effected in the 3rd station. The grazersor browsers entities are lowly effected in the 1st station and the 3rd station, however those very low level effected in the 2nd station. In generally, herbivores are influenced in low level to resilince works in the 1st and 3nd stations, while those include in lowest level in the 2nd station.

Focus on the composition of species identified in the study sites, the species found were small size herbivores, such as *Scarus*spp., *Siganus*spp. and *Acanthurus* spp. which included in a scraper group. The scraper entity haslower effect to resilience works than that for excavators (Obura & Grimsditch, 2009).

The influence of predators (fiscivores) was high level in the 1st and 3rd stations, while it was moderate level in the 2rd station. The influence of indicator fishes of Chaetodontidae family includes in fair level for the 1st station, very low level for the 2nd station, and low level for the 3rd station. The influence of invertivores, especially a damselfish group (Pomacentridae) that also was considered as grazers, included in very high level for all stations, because the damselfishes were highly found in both of species numbers and individual numbers.

Discussion

Reef fish functional groups, such as parrotfishes (Scaridae) and rabbit fishes (Siganidae) found in study area were identified as *excavators, scrapers, grazers* and *browsers,* especially those are the most part of herbivores. Green & Bellwood (2009) stated that herbivores considerably played a role in coral reef resilience remedies, because those have a capability to control and reduce algae growing and then replaced it for coral larvae so that new coral recruitment established on substrates given. The herbivorous fishes essentially play a role in competitive interaction between corals and macro algae. Furthermore, the fishes, especially excavators, a reactively actor in coral bio-erosion and able to create a shifting of growing phases between corals and macro algae, that their processes arenot well understand.

For these reasons, management has to put emphases on the herbivorous fish group, because shifting of herbivorous regimes in coral reefs maysignificantly effect on changes of coral substrates (Berkepile & Hay, 2008; Green & Bellwood, 2009).

Unfortunately, herbivore diversity and their abundance found in the study sites was very low level with majority small body sizes. Most of the species found were herbivorous scrapers, while common species in big sizes and extreme excavators such as *Bolbometopon muricatum* did not appear in the study sites. Small excavators dominantly found in the transect areas were *Chlorurus bleekeri* and *Chlorurus sordidus*. Most of scrapers identified in the areas and ranged from juvenile to adult levels were *Scarus gobban*. Like the parrot fishes and rabbit fishes, also added in group of grazers and browser, they were low levels in species and individual numbers. The assertive rabbit fish was only *Siganus virgatus*. Hence, herbivorous group performances at coral reefs of Pari Islands, even at Pari Lagoon, were relatively insufficient to support coral resilience succession. Their effects might be classified in low and moderate levels. This condition might be non satisfaction of course for ecosystem, based on Thibout *et al*. (2008), the density and diversity of herbivorous functional group were be important to deal with offering guaranty for sustainable growing of coral reef ecosystems. For this reason, the fish groups performing ecological functions must be steady state in order to control the shifting of reef biota regimes.

A large number of individual and biomass of herbivorous fishes was positively correlated with cover of ‘cropped substrata’ (i.e., turf, microalgae, or crustose corallines); however, herbivorous fish populations were never large enough to ‘crop down’ more than about 50 to 65% of substratum (Williams *et al*., 2001). Under the low level of abundance and/or biomass of herbivorous fishes, such as this study, the level are insufficien to control algae growing and coral recruitment. In the study in Great Barrier Reefs, given the abundance of herbivorous fishes was about 0.49 - 0.70 individual/m^2 and biomass was about 0.45 ± 0.08 kg/m^2, effects of grazing on algae and coral percent cover were never large enough to crop down algae coverages and to rise up coral coverages, whereas algae persent cover was still high in mean 56 ± 21% and coral percent cover was remain in a rank from mean 6.0% ± 0.8% to mean 7.7% ± 1.0%. Furthermore, coral recruitment was mean 39 ± 11 colonies/25 m^2 plot. Otherwise, when given abundance was ranged from 4.19 to 5.99 individual/m^2 and biomass was ranged from 3.15 to 4.5 kg/m^2, the effects on algae percent cover, coral percent cover, and coral recruitmen were to be positively running in control the subtratum. Algae coverages were croped down to be 1,7% and 4,7%, coral coverages were increased in ranking from 19.2% ± 2.3% to 20.2% ± 2.2%, whereas coral recruiments were rised to be mean 108 ± 26 and 118 ± 21 colonies /25 m^2 plot (Hughes *et al*., 2007).

Some genus of Pomacentridae and Labridae usually found in coral reef areas (Appendix Table 3). Those are dominant composition of reef fish communities, however those did not entirely be included in herbivorous functional group (grazers). The families of Pomacentridae and Labridae disconformed in assessing coral resilienceisdue to small sizes and wide variety of feeding habits (Obura & Grimsditch, 2009). In Fishbase (Froese & Pauly, 2014), genus of damselfish (Pomacentridae) including in a grazers category and having a feeding territory are *Abudefduf, Amblyglyphidodon, Cheiloprion, Chrysiptera, Dischistodus, Neoglyphidodon, Plectroglyphidodon*, and *Pomacentrus*. Abundance of the genus as mention above in the study sites of Pari Islands is catagorized in more high level than those for herbivores of other families. Folowwing to Casey (2012), damselfishes were grazers that usually have a dominant population among other herbivorous fishes for which damselfishes have significant roles to considerably inûuence the recruitment and post-settlement dynamics of corals.

A damselfish being well known with extremely territorial behaviours is attended to aggressively defence its feeding ground from predators or other grazing species that were bigger in body sizes than that for the damselfish itself. The damselûshes also take care their some key behaviours within their authorities such as grazing turf algae, pecking coral polyps to further propagate algae, weeding unpalatable algae species, and constant aggression against intruders to protect resources (Klumpp & Polunin, 1989; Letourneur *et al*., 1997). The territorial damsefishes cultivate well-definited algal assemblages within their feeding authority and protect them. Hence, the damselfishes may be likely to intensely effect on benthic reef biota (Hata & Kato, 2004; Ceccarelli, 2007). In addition, although the territorial damselûshes inhabit in a wide variety of coral reef, these fishes are usually abundant on shallow reef crests and growing fringing reef and those may have harmful or favourable affects for establishing juvenile corals (Choat, 1991).

Table 1. Effects of functional reef fish group to coral resiliences in the Pari Islands coral reefs

Station	Factors	Variables	*Quality* (ind/350 m2)	*Resilience Indices*					*Weight*	*Influences*
				Very Low (VL) 1	*Low* (L) 2	*Fair* (F) 3	*High* (H) 4	Vary High (VH) 5	*Values*	
1	Herbivores	*Excavators*	17	10 -20					17	VL
		Scarapers	47			40 - 50			141	F
		Grazers/Browsers	26		20 - 30				52	L
	Predators	*Piscivores*	135					>100	675	VH
	Indicators	*Coral Obligate*	40			40 - 50			120	F
	Others	*Invertivores/grazers*	608					> 100	3040	VH
	Means								674	F
2	Herbivores	*Excavators*	0						0	
		Scarapers	25		20 - 30				50	L
		Grazers/Browsers	5	1 - 10					5	VL
	Predators	*Piscivores*	49			30 - 50			147	F
	Indikator	*Coral Obligate*	15	10 - 20					15	VL
	Others	*Invertivores/grazers*	230					> 100	1150	VH
	Means								227	L
3	Herbivores	*Excavators*	13	10 -20					13	VL
		Scarapers	78				70 - 80		312	H
		Grazers/Browsers	24		20 - 30				48	L
	Predators	*Piscivores*	107					> 100	535	VH
	Indicators	*Coral Obligate*	23		20 - 30				46	L
	Others	*Invertivores/grazers*	470					> 100	2350	VH
	Means								551	F

By analysing juvenile coral communities as a function of the temporal turnover of damselûsh territories, Casey *et al*. (2015) found that damselûsh–coral–algae linkages were highly dynamic in reef crest environments. Previous studies showed that the behaviour of territorial grazers on sheltered back reefs had multifaceted impacts on coral recruitment and survival (Letourneur *et al*.,1997; White & O'Donnell, 2010). However, according to Casey *et al*. (2015), the ûndings elucidated the role of territorial damselûshes on the reef crest, which had received much less attention. Thus overall, territorial pomacentrids had a negative impact on juvenile coral abundances; yet, the damselûsh turnover resulted indication of an unexpectedly dynamic system. While juvenile coral abundances could rapidly decline under the cultivation behaviours of a territorial damselûsh, we found that juvenile coral abundance might likewise rapidly recover with the loss of a damselûsh territory. Hence, despite the overall negative inûuence of territorial damselûshes on coral communities, there is potential for coral recovery on reefs occupied by territorial pomacentrids due to these high rates of territorial turnover and subsequent rapid increases in juvenile coral abundances. Corals are sedentary species that are highly sensitive to temporal–spatial shifts in biotic and abiotic regimes (Sandin & McNamara,2012). Consequently, the overall negative impact and the dynamic nature of damselûsh territories on the reef crest have important implications for benthic assemblages on the reef crest.

Another functional group found in the study sites was the carnivory, a top predator in food web, inhabited in reef crasts (1st Station and 3rd station) and consisted of economical prospective families such as rock cods (Serranidae), snappers (Lutjanidae), emperors (Lethrinidae), trevally (Carangidae), goatfishes (Mullidae), spinecheeks (Nemipteridae), sweetlips (Haemulidae), and squirrelfishes (Holocentridae). However, density and diversity of the families included in very low level due to lack of species, while individual numbers varied and rangged from 1 % to 5 %. Mostly the predator were small in sizes, its means under 25 cm. It indicated that there was intensively fishing for the predator (Sadovy *et al*., 2007), for which cumulatively effects migh increase in coral resiliences, especialy due to collectively high controls on other functional groups (Obura & Grimsditch, 2009).

An indicator group of the Chaetodontidae family was discovered in the study sites under lower levels than that in other healt coral reefs (Edrus & Syam, 1998). The dominant species of Chaetodontidae was only *Chaetodon octofasciatus* indicating high level of sedimentation in the study sites. Other species of Chaetodontidae that migh have individual low levels (< 4 individuals) included *Chaetodon collare, Chaetodon lineolatus, Chaetodon speculum, Chelmon rostratus, Heniochus pleurotaenia* and *Heniochus varius.* All of Chaetodontidae species identified in the study sites were included in facultative coralivores and generalist coralivores, thus the Chaetodonts were not included in specialist diet (Pratchett, 2005). Their effects on resiliences ranged from very low to low lavels (Obura & Grimsditch, 2009). The Chaetodonts have a tiny mouth more being preferences to consume coral polyps than that to algae (Reese, 1981), so that their attendance both of species numbers and individual numbers may be insufficience of effecting on coral resilience.

CONCLUSION AND RECOMMENDATION

Reef fish functional groups such as hebivores, carnivores, and indicators that inhabited in Pari Islands, especialy both of density and deversity aspects, migh be classified inadequately state to support for sustainable coral resiliences. In additation, body sizes of the functional groups were included in the lower categories to support resiliences processes, especially there were a lot of the number of tiny grazers and browsers; however, there were a small amount of the excavators. On other hand, piscivores (predators) as competitor of resilience supporting species were found in a quite number.

It's needed to repetitive monitoring on diversity of the fish functional groups and its relationship to new-recruitmen of coral colonies.

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Appendix 1. Study area of Pari Islands (Station 1 up to 3 are transect sites)

Appendix 2. Reef fishes function in food web levels

LEVEL OF FOOD WEB	FUNCTIONAL DESCRIPTION
Herbivores	Exert the primary control on coral-algal dynamics and are implicated in determining phase shifts from coral to algal dominance especially in response to other pressures such as eutrophication, mass coral mortality, etc. E.g. parrotfish (Scaridae), surgeonfish (Acanthuridae).
Piscivores/carnivores	Top level predators, they exert top-down control on lower trophic levels of fish, are very vulnerable to overfishing, and good indicators of the level of anthropogenic disturbance (fishing) on a reef. E.g. sharks, groupers (Serranidae), jacks (Carangidae).
Scavengers /generalists	Second-level predators with highly mixed diets including small fish, invertebrates and dead animals, their presence/absend is a good indicator of anthoropogenic disturbance (fishing). E.g. snappers (Lutjanidae), emperors (Lethrinidae), sweetlips (Haemulidae).
Obligate and facultative coral feeders	The relative abundance of these groups are a secondary indicator of coral community health. E.g. butteflyfish (Chaetodontidae) and some filefish (Monacanthidae).
Sessile invertebrate feeders	Feed on coral competitors such as soft corals and sponges, their relative abundance may be a secondary indicator of abundance/stability of these groups and of a phase shift. E.g. angelfish (Pomacanthidae).
Planktivores	Resident on reef surfaces, but feed in the water column. Their presence/absence may be related to habitat for shelter and water column conditions. E.g. some triggerfish (Balistidae), fusiliers (Caesionidae).
Detritivores	Feed on organic matter in sediment and on reef surfaces, their relative abundance may be an indicator of eutrophication and conditions unsuitable for corals. E.g. goatfish (Mullidae).

Sources: Obura & Grimsditch (2009)

Appendix 3. Feeding behaviour of harbivorous fish reefs

GROUPS	FEEDING BEHAVIOURS
Scrapers/small excavators	Scrapers and small excavators: The majority of parrotfishes (Hipposcarus and Scarus species) are scrapers. They take non-excavating bites and remove algae, sediment and other material by closely cropping or scraping the reef surface, leaving shallow scrape marks on the reef substratum. Scrapers and small excavators (individuals < 35cm standard length) play similar roles in coral reef resilience by limiting the establishment and growth of macroalgae while intensely grazing epilithic algal turf, and providing areas of clean substratum for coral recruitment.
Large excavators/ bioeroders	Large excavators/bioeroders play a similar role in coral reef resilience to scrapers and small excavators. However, they are also major agents of bioerosion on reefs, removing dead coral and exposing hard, reef matrix for coral recruitment. They include all large individuals of excavating species (individuals > 35cm standard length). Five species have also been observed grazing on live corals on Indo Pacific reefs, although coral only accounts for a substantial proportion of the diet of one species (B. muricatum). Since these species have a greater affect on the underlying substratum than scrapers and small excavators, they play a different role in coral reef resilience by opening up new sites for colonization by coralline algae and corals.
Grazers/detritivores	Grazers/detritivores play an important role in coral reef resilience by intensely grazing epilithic algal turfs, which can limit the establishment and growth of macroalgae. Unlike parrotfishes, grazers do not scrape or excavate the reef substratum as they feed. Grazers include most rabbitfishes, small angelfishes (all Centropyge species), and many species of surgeonfishes (all Zebrasoma and Acanthurus species except those that feed on exclusively on plankton or are grazers/detritivores). Grazers/detritivores include Acanthurus species that feed on a combination of epilithic algal turf, sediment and some animal material. Although only a small proportion of their diet is algae, grazers/detritivores are combined with grazers because many are schooling species that can be abundant and consume significant amounts of algal turf.
Browsers	Browsers consistently feed on macroalgae. They select individual algal components and remove only algae and associated epiphytic material. Browsers play an important role in reducing coral overgrowth and shading by macroalgae, and can play a critical role in reversing coral-algal phase shifts. They include some unicornfishes, rudderfishes, batfishes, a rabbitfish and parrotfishes of the genus Calotomus and Leptoscarus.

Source: Berkepile & Hay (2008); Obura & Grimsditch,(2009)

Appendix 4. Species of herbivorous groups identified in the transect sites at Pari Islands

Families/Species		**Herbivory Groups**	**St.03**	**St.02**	**St.01**
SCARIDAE (43%)					
1	*Cetoscarus bicolor*	Excavators			1
2	*Chlorurus bleekeri*	Excavators	5		6
3	*Chlorurus capistratoides*	Excavators	2		3
4	*Chlorurus sordidus*	Excavators	6		7
5	*Scarus dimidiatus*	Scrapers	7		4
6	*Scarus frenatus*	Scrapers	2		3
7	*Scarus ghoban*	Scrapers	62	25	36
8	*Scarus niger*	Scrapers	7		3
9	*Scarus spinus*	Scrapers			1
ACANTHURIDAE (9,5%)					
10	*Acanthurus leneatus*	Grazer/Detritivores	2		2
11	*Ctenochaetus binotatus*	Detritivores	2		
SIGANIDAE (24%)					
12	*Siganus canaliculatus*	Grazers/Browsers			2
13	*Siganus javus*	Grazers/Browsers	2		
14	*Siganus guttatus*	Grazers/Browsers			2
15	*Siganus punctatus*	Grazers/Browsers	2		4
16	*Siganus virgatus*	Grazers/Browsers	6		6
POMACANTHIDAE (14%)					
17	*Centropyge eibly*	Grazers/Inventivores	2		2
18	*Chaetodontoplus mesoleucus*	Grazers	5	5	6
19	*Pomacanthus sexstriatus*	Grazers/Detritivores	1		2
KYPHOSIDAE (9,5%)					
20	*Kyphosus vaigiensis*	Browsers	1		
21	*Platax teira*	Browsers	1		

Appendix 5. Reef fish Species based on functional groups identified in the transect sites at Pari Islands

COMMON FUNCTIONAL GROUPS					
Families/Species		Groups	St.03	St.02	St.01
CARANGIDAE (2%)					
1	Caranx bajaj	Fiscivores/Scavengers	5		
2	*Sphyraena flavicauda*	Fiscivores/Scavengers			26
HAEMULIDAE (1%)					
3	*Plectorhyncus chaetontoides*	Fiscivores/Scavengers	1		
LETHRINIDAE (3%)					
4	*Lethrinus harak*	Fiscivores/Scavengers	1		
5	*Lethrinus erythropterus*	Fiscivores/Scavengers	1	1	1
6	*Lethrinus ornatus*	Fiscivores/Scavengers	1		1
LUTJANIDAE (4%)					
7	*Lutjanus biguttatatus*	Fiscivores/Scavengers	24	6	9
8	*Lutjanus carponatus*	Fiscivores/Scavengers		1	1
9	*Lutjanus decussatus*	Fiscivores/Scavengers	7	1	4
10	*Lutjanus fulviflamma*	Fiscivores/Scavengers	2		6
MULLIDAE (2%)					
11	*Parupeneus macronema*	Fiscivores/Scavengers	1		
12	*Upeneus tragula*	Fiscivores/Scavengers	2	2	2
SERRANIDAE (4%)					
13	*Cephalopholis boenack*	Fiscivores/Scavengers	2	1	2
14	*Cephalopholis cyanostigma*	Fiscivores/Scavengers			2
15	*Chepalopholis sexmaculata*	Fiscivores/Scavengers	1		
16	*Ephinephelus fasciatus*	Fiscivores/Scavengers	1		1
HOLOCENTRIDAE (2%)					
17	*Myripristis kunteee*	Fiscivores/Scavengers	2		
18	*Sargocentron rubrum*	Fiscivores/Scavengers	4		12
NEMIPTERIDAE (5%)					
19	*Pentapodus trivittatus.*	Fiscivores/Scavengers	6	1	5
20	*Scolopsis bilineata*	Fiscivores/Scavengers	6		4
21	*Scolopsis ciliata*	Fiscivores/Scavengers	4	8	2
22	*Scolopsis lineata*	Fiscivores/Scavengers	8		6
23	*Scolopsis margaritifer*	Fiscivores/Scavengers	3	2	6
CAESIONIDAE (2%)					
24	*Caesio cuning*	Planktivora	21	26	45
25	*Caesio caerulaureus*	Planktivora	4		
PHEMPHERIDIDAE (1%)					
26	*Pempheris oualensis*	Planktivora	8		
POMACENTRIDAE (31%)					
27	*Abudefduf bengalensis*	Invertivores/grazers	23		18
28	*Abudefduf sexfasciatus*	Invertivores/grazers	38	25	75
29	*Abudefduf vaigiensis*	Invertivores/grazers		52	18
30	*Acanthochromis polyacanthus*	Invertivores/grazers	4		24
31	*Amblyglyphidodon aureus*	Invertivores/grazers	2		
32	*Amblyglyphidodon curacao*	Invertivores/grazers	74	32	83
33	*Amblyglyphidodon leucogaster*	Invertivores/grazers	78		41
34	*Amblyglyphidodon ternatensis*	Invertivores/grazers		26	
35	*Cheiloprion labiatus*	Invertivores/grazers			12
36	*Chromis antipectoralis*	Invertivores	96		74
37	*Chromis ternatensis*	Invertivores	132		87
38	*Chrysiptera glauca*	Invertivores/grazers	4		3
39	*Dischistodus perspicillatus*	Invertivores/grazers		6	2
40	*Dischistodus prosopotaenia*	Invertivores/grazers	6		24
41	*Lepidozygus tapeinosoma*	Invertivores	126		
42	*Neopomacentrus azysron*	Invertivores	86	25	124
43	*Neopomacentrus cyanomus*	Invertivores	75		
44	*Neopomacentrus filamentosus*	Invertivores	102	15	112
45	*Neoglyphidodon melas*	Invertivores/grazers	5	16	9
46	*Neoglyphidodon nigrosis*	Invertivores/grazers	4		28
47	*Plectroglyphidodon lacrymatus*	Invertivores/grazers	13		4
48	*Pomacentrus amboinensis*	Invertivores/grazers	46		24
49	*Pomacentrus alexanderae*	Invertivores/grazers	78		66
50	*Pomacentrus burroughi*	Invertivores/grazers			38
51	*Pomacentrus grammorhynchus*	Invertivores/grazers	16	8	25
52	*Pomacentrus littoralis*	Invertivores/grazers			12
53	*Pomacentrus moluccensis*	Invertivores/grazers	47	14	58
54	*Pomacentrus philippinus*	Invertivores/grazers	15		
55	*Pomacentrus spilotoceps*	Invertivores/grazers		5	12
56	*Premnas biaculeatus*	Invertivores/grazers	3	3	4
57	*Stegastes nigricans*	Invertivores/grazers	14	43	28

Appendix 5. *continued ....*

LABRIDAE (25%)					
58	*Bodianus mesothorax*	Invertivores	1		3
59	*Cheilinus fasciatus*	Invertivores	3	16	12
60	*Cheilinus trilobatus*	Invertivores	8		8
61	*Cheilinus undulatus*	Invertivores	1		1
62	*Choerodon anchorago*	Invertivores	4	8	24
63	*Cirrhilabrus cyanopleura*	Invertivores	62		75
64	*Coris veriegeta*	Invertivores	4		5
65	*Diproctacanthus xanthurus*	Invertivores	4		4
66	*Epibulus insidiator*	Invertivores	6	2	6
67	*Gomphosus varius*	Invertivores	3		2
68	*Halichoeres argus*	Invertivores	4	18	12
69	*Halichoeres chloropterus*	Invertivores			5
70	*Halichoeres hortulanus*	Invertivores	4		8
71	*Halichoeres lamari*	Invertivores	3		2
72	*Halichoeres purpurescens*	Invertivores	7	1	6
73	*Halichoeres scapularis*	Invertivores		2	2
74	*Halichoeres vrolokii*	Invertivores			4
75	*Hemigymnus melapterus*	Invertivores	7	6	12
76	*Labrichthys unilineatus*	Invertivores	2		2
77	*Labroides dimidiatus*	Invertivores	5	2	8
78	*Pseudocheilinus hexataenia*	Invertivores			3
79	*Stethojulis bandanensis*	Invertivores	3		8
80	*Thalassoma amblycephalum*	Invertivores	22		44
81	*Thalassoma hardwickii*	Invertivores			6
82	*Thalassoma lunare*	Invertivores	38	2	24
CHAETODONTIDAE (7%)					
83	*Chaetodon collare*	Facultative/Indicator	1		
84	*Chaetodon lineolatus*	General/Indicator			1
85	*Chaetodon octofasciatus*	Generalist/Indicator	16	15	34
86	*Chaetodon speculum*	Facultative/Indicator			1
87	*Chelmon rostratus*	Facultative/Indicator	4		
88	*Heniochus pleurotaenia*	Generalist/Indicator	2		3
89	*Heniochus varius*	Generalist/Indicator			1