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Linking the feeding regime of *Chaetodon octofasciatus* to the coral health in Redang Island, Malaysia

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Abstract—Relationship between the feeding regime of the coral feeding butterflyfish, *Chaetodon octofasciatus* and the coral reef health were investigated across five reefs around Redang Island, Malaysia. Feeding and territorial behavior for a total of 15 pairs butterflyfishes were studied by using visual census observation approach. Ranging behavior, territories size, activity patterns, individual bite rates and types of food consumed were recorded. *C. octofasciatus*, the most common butterflyfish of Redang Island, feeds on different coral polyps, particularly on genus *Acropora*. The pairs of this species occupy feeding territory, of which they exclusively defended against conspecifics and congeneric intruders. A total number of 27 coral genera were identified within all study sites, of which coral community was typically dominated by genera *Acropora* and *Porites*. Percentages of live coral coverage among 5 sites were ranged from 48.87% to 63.21%, indicated that Redang Island's coral conditions were ordinarily "good". Our finding has shown the positive correlation between the abundance of *C. octofasciatus* with percentage live coral cover and *Acropora* cover. The feeding territories size, which ranged from 16.4 to 50.1 m^2, showed no correlation with live coral cover. The feeding rates in all study sites varied from 6.0 to 9.9 bites min^{-1}, with an average of 7.9 bites min^{-1}, were not significantly related to either coral cover or the size of feeding territory. *C. octofasciatus* is diurnal and spends about 47% of the time budget in feeding activity. The remaining time is spent in other activities such as swimming, hanging, sheltering and territory defending.

Key words: Feeding regime, *C. octofasciatus*, coral health, live coral coverage, territory size

Introduction

Coral reefs are among the most diverse, complexity and productive ecosystems on Earth. They offer important natural, economic and recreational resources for many countries throughout the tropics. Coral reefs harbor about a third of all species of bony fishes (Sorokin 1993), and are originally served as a natural feeding regime for many marine organisms living in this ecosystem.

In recent years, there are many studies revealed that coral habitats around the world are suffering severe degradation resulted from natural disturbances and anthropogenic disturbances (Randall 1974, Hourigan et al. 1988, Bouchon-Navaro and Bouchon 1989). Coral and coral reefs are extremely sensitive. Slight changes in the reef environment may have detrimental effects on the health of entire coral colonies (Hourigan et al. 1988). Hence, both types of disturbances can alter the overall coral cover and the structural forms of corals present on a reef. The coral reef therefore is not the static solid structure and it is an ever-changing complex community (Randall 1974).

Butterflyfishes of the family Chaetodontidae are conspicuous inhabitants of coral reef ecosystem worldwide (Motta 1989) characterized as diurnally active, brightly colored fish belonging to three trophic groups: corallivorous, benthic omnivores and planktivores. Coral feeder chaetodontids being mainly in close association with the reef habitat for both food and shelter, generally live in monogamous pairs and have broad home ranges or territories (Reese 1977, 1981, Hourigan et al. 1988, Hourigan 1989, Crosby and Reese 1996, Öhman et al. 1998). Reese (1977, 1981) has first proposed the use of obligate corallivorous butterflyfish as bio-indicator organisms for the coral health. These species are so sensitive that may rapidly detect and show a response to changes in reef conditions via their abundance, distribution and behaviors. Since the hypothesis was first published, an array of studies has documented positive correlation between chaetodontid diversity and abundance of live coral cover or coral species richness (Bell and Galzin 1984, Findley and Findley 1985, Bouchon-Navaro and Bouchon 1989, White 1989, Öhman et al. 1998, Syms 1998). In contrast, Roberts and Ormond (1987) had shown conflicting evidence in their study.

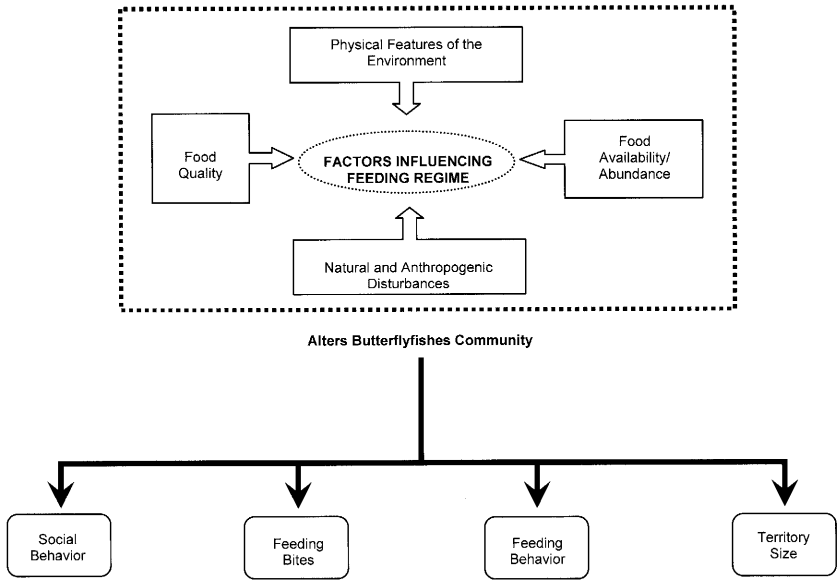

Fig. 1. General linkages of butterflyfishes community and feeding regime.

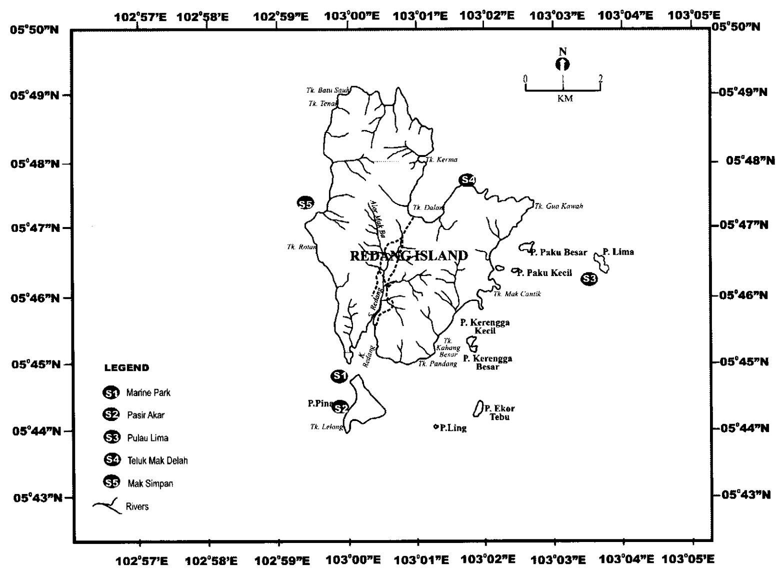

Fig. 2. Map showing 5 study sites at Redang Island, Malaysia.

Determination of effective feeding regime requires an understanding of interactions and relationships between fish community and food quality within the regime. Changes in feeding regime conditions may alter the fish's abundance and behaviors (Fig. 1). Consequently, the aim of this study is to investigate the effect of coral cover on local chaetodontids abundance, fish feeding habits, territorial behaviors and their social system, and the data are used to evaluate the connectivity between feeding regime and coral reef health.

Material and Methods

Study area

Research was carried out at Redang Island archipelago which is located approximately 45 km off the east coast of Peninsular Malaysia. It is the largest of the group of islands dotting the South China Sea, which is about 25 km^2 in area. Five study sites with different condition were located around Redang Island had been selected (Fig. 2). All sites are covered by fringing reefs with depth between 5–25 m. The sampling sites, their locations, depths, temperature and salinity are listed in Table 1. Data were collected through four field trips, which conducted within 29th July–5th August 2003, 11th–14th May 2004, 22nd–25th July 2004 and 9th–12th September 2004.

Study species

The eight-banded butterflyfish, *Chaetodon octofasciatus*, has a yellow to white body with eight black

Table 1. List of the study sites and their physical parameters.

Sites	Name	Latitude (°N)	Longitude (°E)	Depth (m)	Temperature (°C)	Salinity (‰)
1	Marine Park	05.44.81	102.59.99	3.4	29.4	33.0
2	Pasir Akar	05.44.59	102.59.98	9.5	30.0	33.0
3	Pulau Lima	05.46.40	103.03.54	6.0	30.0	33.0
4	Teluk Mak Delah	05.47.52	103.01.83	7.8	29.5	34.0
5	Mak Simpan	05.47.32	102.59.51	5.5	30.0	32.5

bands. It has a black stripe along the top of the snout and a clear caudal fin margin. This species is endemic to water within Redang Island and an adult grows to 12 cm in total length (Myers 1991, Mohsin and Ambak 1996). Typically, this species inhabits in areas with a rich coral cover at depths less than 20 m, and is distributed broadly in tropical marine waters from Japan, Malaysia, western Pacific and extending to Indian Ocean (Mohsin and Ambak 1996). Juveniles usually occur in group among tightly branching *Acropora* corals, whilst adults form a small schools or living in pairs, typically associated with branching or foliose hard corals. It feeds exclusively on coral polyps (obligate corallivorous) and defends small, long-term territories (Myers 1991).

Field observation

All observation was carried out during daylight hours between 0800 and 1800 h, to avoid the diurnal variation of the fish community (Bouchon-Navaro and Bouchon 1989, English et al. 1994, Righton et al. 1998). All work was performed by SCUBA diving on the reef at depths varying from 3 to 10 m. Fifteen pairs of fishes were selected in five sites and their abundance, territory size, territorial behavior, feeding behavior and activity patterns (time budgets) had been investigated. Pairs were followed at a distance greater than 1m to minimize the influence on the foraging path or natural behavior of fish (Reese 1975, Tricas 1989, Wrathall et al. 1992, Righton et al. 1998). Diver impact was also minimized by initiating fish counts 5–10 minutes after the line was laid out (Crosby and Reese 1996, Öhman et al. 1998).

Fish abundance

A belt transect method was utilized to estimate the abundance of *C. octofasciatus* (Crosby and Reese 1996). At each site, ten-10 m long transect lines were laid randomly and parallel to the shoreline. Visual census of fishes was conducted by slowly diving along a line and all the number of fishes within 2.5 m of either side of the line was counted and recorded. Thus, provided a sampling area of 50 m^2, and the total surface surveyed on the studied reef was 2500 m^2 (500 m^2 each site).

The size of territories and territorial behavior

Pairs were followed and observed for 30 min, which is adequate to plot permanent territory boundary precisely. The feeding territories were marked by placing color-tagged nails at the position where the fishes hesitate and turn back into their territory, and also at the position that aggressive interaction (display or chases) encountered (Crosby and Reese 1996). Zekeria and Videler (2002) showed that increasing the observation time beyond 30 min did not change the size of the territories significantly.

The size of the territories was estimated using a modified method of Crosby and Reese (1996). The length of the territory along the longest axis was measured using a measuring tape. The widths of the territories were then measured from all position of markers to the longest axis. All width measurements were taken perpendicular to the long axis. The territories were plotted to scale on graph paper and their sizes estimated by counting the number of square centimeters enclosed within the territories.

Feeding behavior

Feeding behavior and prey selection were quantified by following one individual (male or female) within each pair of fishes for three-10 m periods. Feeding bites were tallied and the consumed type of coral recorded. In the present study, we assume that the behavior of one individual was representative of both. Hence, one of the pair was randomly selected and followed for the entire observation period.

Activity patterns

The activity patterns and time budget of 15 pairs *C. octofasciatus* were assessed by following for a period of 30 min per individual. The activity was classified into six categories (Righton et al. 1998) as shown in Table 2.

Coral community parameters

Part of the coral data used in the present study was provided by Kok (2004). These data was assessed via the same 10 m transect lines which applied in fish census counting survey during the first session trip. The coral data included the coral coverage of three benthic communities: live coral cover, dead coral and other bottom. Live coral been divided into

Table 2. Description of six categories of activity patterns.

Activities	Description
Feeding	– A fish was either inspecting a color at close range (swim close to the substrate at low speed) @ taking a bite.
Swimming	– Fish swim at a faster speed, a few cm above the substrate @ patrolling territory borders.
Agonistic interaction	– A fish displays aggressive behavior in defending its territory @ in response to aggression by others. For instance: aggressive display (advertisement), chases and attack.
Hovering	– Hanging (stationary) in the water column.
Sheltering	– A fish hidden and rest in coral colonies.
Crowding	– Pair fish member meet up and assemble after a separation.

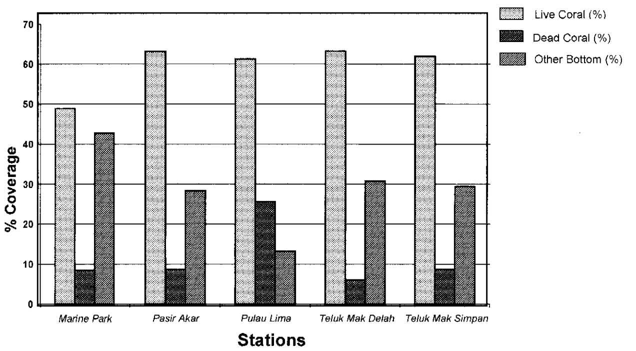

Fig. 3. Percentage of covers of live corals, dead corals and other bottoms in Redang Island, Malaysia.

scleractinian and non-scleractinian coral. Dead corals are defined as corals which just die and covered by algae. Other bottom included other invertebrates and substrates for instance sandy patches, rubbles and rock. Reef's condition was estimated using the criteria of the ASEAN-Australia Living Coastal Resources project with >75%=excellent, 75–50%=good, 50–25%=fair and <25%=poor (English et al. 1994).

Data analysis

For data analysis, both parametric and non-parametric tests were applied. All statistical probabilities are two-tailed. The Spearman correlation coefficient was used to investigate the relationships between the abundance of *C. octofasciatus* and coral community parameters. Relationships among size of territory, coral cover and feeding rate were also determined by using Spearman correlation coefficient. ANOVA (Analysis of Variance) was used to look at site differences. Statistics were all performed using the Microsoft Excel 2003 and the Statistical Package for the Social Science (SPSS V12).

Results and Discussion

Coral cover in certain environment is greatly affected by the distribution of hard substratum on a reef as well as by the health of the *in-situ* living corals. Reef health was assessed, which were conducted in 5 sampling sites at depths between 3 to 10 m. The results of the quantitative benthic surveys for all sites were shown in Fig. 3. Table 3 shows some information about the size, condition, live coral and acroporids coral cover of 15 territories in 5 sites. The results indicated that, majority of the selected sites were in "good" condition. Mean live coral coverage was 59.7% for all sites combined. The mean coral coverage was slightly low in Marine Park which is 48.9% compare to others four sites. This may be subjected to the domino effect of tourist activities such as snorkeling and scuba diving in the affected reefs (Mazlan et al. 2002). Consequently, reefs in overall Redang Island were categorized into "good" condition. Results of the present study were in fully agreement with more detailed study conducted by Harborne et al. (2000). A total number of 27 coral genera were identified within all study sites that was dominated by at least 4 main genera such as *Acropora*, *Porites*, *Seriatopora* and *Fungia* respectively. Total coverage of these 4 genera in a transect line was 49.2% in average (Kok 2004).

Chaetodon octofasciatus was extremely abundant at all study sites, especially at Marine Park, Mak Simpan and Teluk Mak Delah, which represented by 96, 96 and 63 no of individuals respectively. The relationships between *C. octofasciatus* abundance and living coral coverage have been investigated. The results were as shown in Fig. 4 denoted that there were positive correlations between percentages of coral cover again number of fish individuals. Similar results were also reported elsewhere (Adrim and Hutomo (1989); Bouchon-Navaro and Bouchon (1989); Manthachitra et al. (1991) and Öhman et al. (1998). Spearman rank correlation coefficients were used to examine these relationships, and showed that the abundance of *C. octofasciatus* seems to be more significantly correlated with the percentage of *Acropora* coral cover ($r_s=0.55$, $p<0.01$). In contrast, several studies have also found no correlations, or weak correlations between these relationships (Findley and Findley 1985, Cox 1994).

C. octofasciatus lives in heterosexual pairs, foraged and patrolled within relatively small territories. Mean territorial size was 28.4 m^2 ($\pm 12.0\ m^2$) and ranged between 16.4 m^2 to 50.1 m^2 across all sites (Table 3). Tricas (1989) found that territory area of butterflyfish was positively correlated with coral abundance, where territories will be adjusted as an in-

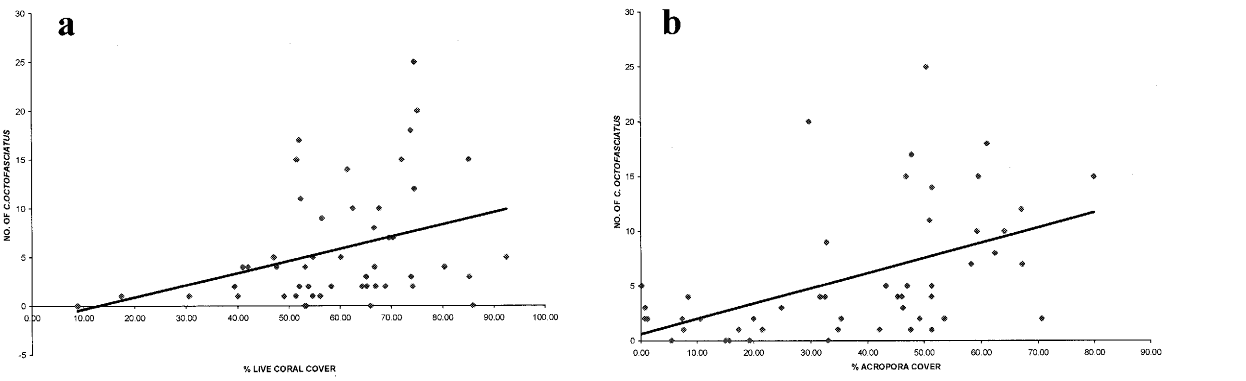

Fig. 4. Correlation between (a) % live coral cover and (b) % *Acropora* coral cover with total numbers of *C. octofasciatus* in the Redang Island, Malaysia.

Table 3. Mean coral cover (%), *Acropora* cover (%), territory size (m^2), and condition of 15 territories in 5 study sites at Redang Islands. All variables are mean±s.d.

Stations	Marine Park	Pasir Akar	Pulau Lima	Teluk Mak Delah	Mak Simpan
Condition	Fair	Good	Good	Good	Good
Coral cover (%)	48.87	63.13	61.25	63.21	61.89
Acropora cover (%)	37.74±14.8	18.79±24.4	32.86±15.8	54.00±19.6	44.27±17.0
Territory size (m^2)	19.9±9.4	30.5±7.4	25.0±10.0	50.1±20.4	16.4±12.9

versely function of competitor abundance and related area of defense. Present findings showed that the mean territory size was significantly different between sites (one-way ANOVA $F_{2,5}=23.0$, $p<0.05$). However, no significant correlation was observed between the size of the territories and the coral cover ($p>0.05$).

In-situ observation on ranging behavioral studies demonstrated that *C. octofaciatus*, although present in abundance, established a relatively small size territory, and showed high tendencies of hiding in between corals branches. Their ability to maneuver swimming in between the coral branches and crevices was extraordinarily good. They appeared to be strictly resided in the same areas of the reef (side attached) and defend these areas. The usual behavior for this species was wandering about in its territory, hovering and then to bite off a coral polyp and occasionally chase away an intruder from their territory. During the observations, we found that the pair's members were usually separated by less than 1m as they foraged throughout their territory and regularly patrolled territory borders. Table 4 showed the relative comparison of activities budget (expressed as mean percent activities as denoted by different sizes of solid circles) between 5 study sites. A total of 15 pairs of *C. octofasciatus* were observed and the results were based on approximately 450 hours of underwater observation periods.

C. octofasciatus spent approximately 47% of their time foraging on live coral. Foraging involved travel between coral heads, inspection and consumption of coral tissue (Tricas 1989). Feeding took place primarily at territory border, and pairs tended to follow a feeding circuit around the territory (Righton et al. 1998). The feeding rate in the 5 study sites varied from 6.0 to 9.9 bites min^{-1} with an average of 7.9 bites min^{-1} (±1.4) (Table 5). No correlation between feeding rates and territory size ($r_s=-0.3$, $p>0.05$) was found in the present study. The rate of feeding was significantly not correlated with the size of the territory between sites (one-way ANOVA $F_{2,5}=11.8$, $p<0.01$).

Swimming is the major non-feeding activity and it took 20% of the daily time budget. Swimming activity included patrolling the boundary of the territory. Swimming was sometimes followed by advertisement and display towards intruders (Agonistic interaction) as a meaning of defending their territories. Occasionally the warning display was followed by a chasing or direct attack by the defending pairs (more intense forms of aggression). Agonistic interaction accounted for about 12% of the time budget, 11% was spent sheltering in refuge, 6% crowding and only 4% spent hanging (hovering) in the water column, which is rarely observed behavior (Table 4).

C. octofasciatus is a generalist coral feeder. Individuals were observed feeding only on scleractinian corals, taking a broad range of species from several genera (Table 5). In the present study, this species clearly showed strong preferences on feeding *Acropora* corals, which consisted approximately 62% of its daily diets. Bouchon-Navaro (1981) and Manthachitra et al. (1991) also reported that *C. octofasciatus* is always found associated with acroporid corals. The feeding preference and avoidance of these chaetodontids depend on

Table 4. Time budgets (% of mean frequency) for 6 main activities at 5 study sites in Redang Islands. (Solid circles depicted various scales of activities).

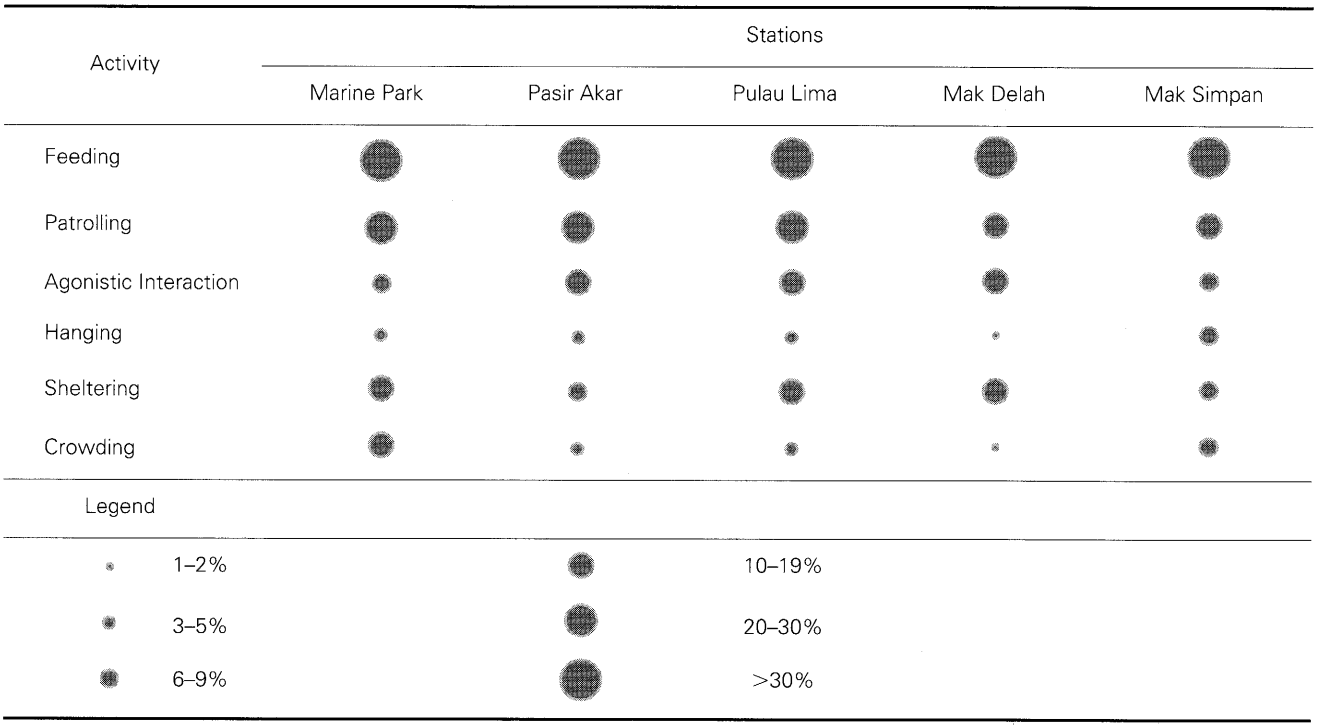

Table 5. Feeding rate (bites per min) and diet of *C. octofasciatus* inhabiting in five study sites. (Figures shown are mean±s.e. N=15 for all parameters).

Station	Marine Park	Pasir Akar	Pulau Lima	Mak Delah	Mak Simpan
Feeding rate (bites min^{-1})	7.5±2.7	7.4±0.9	6.0±2.1	8.5±0.7	9.9±0.7
Diet (x% bites)					
Acro	71.8	51.2	45.5	61.4	79.2
Monti	14.8	13.0	9.9	6.2	1.9
Pori	3.0	0.4	0.4	6.6	8.8
Fung	0.0	11.8	33.8	0.0	2.3
Pavo	0.0	3.4	0.0	0.0	1.1
Other	6.4	16.5	2.6	23.4	6.4

Abreviation of coral genera: Acro=*Acropora*, Monti=*Montipora*, Pori=*Porites*, Fung=*Fungia*, Pavo=*Pavona*, Other=other coral genera.

both biting rate and food availability in the environment rather than on biting rate alone.

Conclusion

Coral reefs supporting very diverse fish assemblages are important resources for many species of coral reef fishes. Among coral-reef fishes, the species that are most likely to be affected by coral disturbances are obligate corallivorous fish species, including butterflyfishes (Chaetodontidae). Changes in fish feeding regimes as a result of coral disturbance will alter fish's abundance and behavior. Fish communities respond to disturbance in various ways depending on the type and degree of perturbation. Feature of behavior are among the most important ecological adaptations of animals to environmental conditions. The behavioral reactions of fishes are interconnected with their morphology and physiology. The relevant finding of the present study was that the increase in number of fishes was positively correlated to the increase in coral coverage's. With respect to this obligate corallivores of chaetodontids fishes, it is envisaged that degraded health condition of a coral reef as manifested by degraded quality of the stressed coral polyps, will result in a decrease in the abundance and diversity of these species and consequently, will increase territorial size, feeding regimes, feeding rate and agonistic encounters as mated pairs attempt to maintain their nutritional intake by expanding their territories to include more coral colonies. After a time, feeding rates may actually decrease as more time is spent defending territories from neighboring pairs.

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