Trophic structure of reef fishes and relationship of corallivore fishes with hard coral in Kepulauan Seribu, Jakarta

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Abstract. Corallivore became one of the biotic components that relate with coral coverage. The objective of this study was to determine the trophic structure of reef fishes, as well as the relationship between corallivores and hard corals in the northern part of Kepulauan Seribu. Reef fish species and benthic coverage were assessed using underwater visual census (UVCs) and Line Intercept Transect (LIT). The results showed that there were 120 reef fish species belonging to 7 trophic groups and 19 families. Pomacentridae and Labridae are the most abundant fish families. Based on reef fish components, Sepa Besar reef fish characteristics were dissimilar than the other sites. The highest coral cover was found in Pelangi Island, which related with the high abundance of corallivores. An abundance of corallivore groups showed a positive correlation ($R^2 = 0.7786$) with hard coral cover. The abundance and diversity of reef fish were affected by the availability and variety of food. Our study shows that coral covers affect the abundance of corallivore fishes. Variability and existence of food for reef fishes are really important for resort proprietors to be aware of especially for those who manage diving and snorkeling activities.

Keywords: coral association, food availability, reef fish, Kepulauan Seribu

1. Introduction

The structure of coral reefs is determinant on the structure of coral-associated fish assemblages [1]. Coral reefs are known to be strongly associated with fish communities, which represent one of the most important biotic components in coastal ecosystems [2-4] and utilize it as territories [5], feeding grounds [6], shelter [7], and reproduction as well as spawning grounds [8]. Many studies have presented that habitat structures [9], latitude [10] and coral cover [1] are particularly important variables affecting the diversity and abundance of reef fishes. The Kepulauan Seribu tropical reefs are located in Jakarta Bay, Indonesia [11]. Kepulauan Seribu coral reefs have suffered significant impacts by different kind of pressures including local anthropogenic activities [12]. The diversity of reef fishes across the Kepulauan Seribu is presented in the previous study [13], where the archipelago is divided into five sub-districts, showing a disturbance gradient on the Kepulauan Seribu coral reefs. Disturbances coming from Jakarta are causing a severely polluted nearshore reef, that is decreased in offshore reefs [14]. Coral reefs closer to the disturbances display lower diversity [15]. The depletion of coral cover also affected the structure of reef fishes. Coral degradation is an important factor.
affecting the reef fish community [16, 17]. Specific coral reef fishes are dependent on coral habitat for food resources [4]. Most species of reef fish that feed on coral colonies are corallivores and herbivores. Herbivorous fish only consume the algae which cover the corals, while corallivorous fish are the predators for coral [18]. Assessments of the fish community structure and the relationship between specific coral-feeding fish with the corals are important because it could give information about reef fish trophic character in the northern region of Kepulauan Seribu and assessed the coral health of the reef by relating it with the existence and abundances of corallivorous fish. The goal of this study was to determine the trophic structure of reef fish and the relationship between corallivorous fish with hard coral at three resort islands in the northern part of the Kepulauan Seribu archipelago. This study could give awareness to the resort proprietor about the condition of the coral reef ecosystem around the islands and is able to the baseline monitoring information because these islands have various local anthropogenic impact from the resort activities such as diving and snorkeling.

2. Materials and Methods

Reef fish communities and benthic cover were observed at three stations on Sepa Besar Island (Sepa Besar 1, Sepa Besar 2 and Sepa Besar 3), Papatheo Island (Papatheo 1, Papatheo 2 and Papatheo 3) and Pelangi Island (Pelangi 1, Pelangi 2 and Pelangi 3) (figure 1). Those islands are commonly known as resort islands and every island has several diving spots for divers that stay in those islands.

![Figure 1. Coral reef ecosystem observation location on north region of Kepulauan Seribu.](image)

This study was carried out at each site between 09.00 and 16.00 from 25th to 29th August 2016. Reef fish species and their abundance were estimated with underwater visual census (UVCs) and benthic coverage using line intercept transect (LIT) [19] along transects 100 m² with three replicates per site. This sampling involved identifying and counting all fish observed and also identifying all benthic covers under the transects along 20 m long transects. Reef fish sampling excluded the high activity periods of early morning and late afternoon to avoid higher data error [19, 20]. Data were collected at representative shallow water habitats (<10 m depth) in all study sites. After data collection, reef fish identification was confirmed by using standard reef fish identification books [21-24]. Reef fish were classified into seven categories of trophic groups (benthic invertivore, corallivore, carnivore,
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The most abundant fish families in all study sites were Pomacentridae (23 species in Sepa Besar Island, 24 species in Papatheo Island and 20 species in Pelangi Island) and Labridae (22 species in Sepa Besar Island, 12 species in Papatheo Island and 9 species in Pelangi Island) (figure 2). Pomacentridae and Labridae are also the dominant reef fish species in other locations in Indonesia [28-31]. There were several reef fish families that were only found in one island such as Carangidae and Mullidae in Sepa Besar Island, Blenniidae in Papatheo Island and Centriscidae, Lutjanidae, and Muraenidae in Pelangi Island. The fact that Pomacentridae was the most abundant family (figure 3) is not surprising, as it is known to be their natural habit to swim around coral reef ecosystems in large groups [32].

In addition, this present study shows five Pomacentridae species with higher relative abundance (above 139 ind/100 m²). These are Abudefduf sexfasciatus, Amblyglyphidodon curacao, Pomacentrus alexanderae, Pomacentrus molucensis and Pomacentrus smithi, with the most abundant species being Pomacentrus alexanderae (around 278 ind/100 m²) (table 1). This is in agreement with previous studies that show that this species are known to be predominantly more abundant than other reef fish species in the Kepulauan Seribu [31].
Figure 3. Comparison of the number of reef fish species from each family that were found in the study sites, Sepa Besar; Papatheo; Pelangi.

Table 1. List of taxa in all study sites (*individuals≤139, **individuals≤278, ***≤417 based on the reef fish relative abundance).

| Fish species                        | Sepa Besar | Papatheo | Pelangi |
|-------------------------------------|------------|----------|---------|
| APOGONIDAE                          |            |          |         |
| Apogon compressus                   | +          |          | +       |
| Apogon cyanosoma                    |            |          |         |
| Apogon komodoensis                  | +          |          |         |
| Apogon selas                         |           |          |         |
| Apogon seleii                        |            |          | +       |
| Apogon taeniophorus                  |            |          | +       |
| Apogon thermalis                     |            |          |         |
| Archamia zosterophora                |            |          |         |
| Cheilodipterus quinquelineatus       |            |          | +       |
| Pterapogon kauderni                  |            |          |         |
| BLENNIIDAE                           |            |          |         |
| Petroscirtes breviceps               |            |          |         |
| CAESIONIDAE                          |            |          |         |
| Caesio caeruleaureus                 | +          |          |         |
| Caesio cuning                        |            |          | +       |
| Caesio lunaris                       |            |          | +       |
| CARANGIDAE                           |            |          |         |
| Trachinotus baillonii                |            |          |         |
| CENTRISCIDAE                         |            |          |         |
| Aeoliscus strigatus                  |            |          | +       |
| CHAETODONTIDAE                       |            |          |         |
| Chaetodon melannotus                 |            |          |         |
| Chaetodon octofasciatus              | +          |          | +       |
| Coradin chrysozonus                 |            |          | +       |
| Heniochus pleurotaenia               |            |          | +       |
| Heniochus varius                     |            |          | +       |
| EPHIPPIDAE                           |            |          |         |
| Platax teira                         |            |          | +       |
| HOLOCENTRIDAE                        |            |          |         |
| Myripristis berndti                  |            |          | +       |
| Sargocentron rubrum                  | +          |          |         |
| Sargocentron violaceum               | +          |          |         |
| LABRIDAE                             |            |          |         |
| Anampses caeruleopunctatus           |            |          | +       |
| Anampses geographicus                |            |          | +       |
| Anampses meleagrides                 |            |          | +       |
| Cheilinus chlorourus                 |            |          | +       |
| Fish species                        | Sepa Besar | Papatheo | Pelangi |
|------------------------------------|------------|----------|---------|
| *Cheilinus digramma*               | +          |          |         |
| *Cheilinus fasciatus*              | +          | +        | +       |
| *Choerodon anchorage*              | +          |          |         |
| *Cirrhilabrus solorensis*          | +          |          | +       |
| *Diproctacanthus xanthurus*        | +          |          |         |
| *Epibulus insidiator*              | +          | +        | +       |
| *Gomphosus caeruleus*              | +          |          |         |
| *Halichoeres hortulanus*           | +          | +        | +       |
| *Halichoeres leucurus*             | +          |          |         |
| *Halichoeres melanochir*           | +          |          |         |
| *Halichoeres melanurus*            | +          | +        | +       |
| *Halichoeres richmondi*            | +          | +        | +       |
| *Halichoeres trimaculatus*         | +          |          | +       |
| *Halichoeres xanti*                | +          |          |         |
| *Hemigymnus melapterus*            | +          |          |         |
| *Labrichthys unilineatus*          | +          |          |         |
| *Labroides dimidiatus*             | +          | +        | +       |
| *Stethojulis albovittata*          | +          |          |         |
| *Stethojulis interrupta*           | +          |          |         |
| *Thalassoma hardwicke*             | +          |          |         |
| *Thalassoma lunare*                | +          | +        | +       |
| **LUTJANIDAE**                     |            |          |         |
| *Lutjanus decussatus*              | +          |          |         |
| **MULLIDAE**                       |            |          |         |
| *Parupeneus macronema*             | +          |          |         |
| **MURALIDAE**                      |            |          |         |
| *Gymnothorax javanicus*            | +          |          |         |
| **NEMIPTERIDAE**                   |            |          |         |
| *Pentapodus trivittatus*           | +          |          |         |
| *Scolopsis bilineata*              | +          | +        | +       |
| *Scolopsis ciliata*                | +          | +        | +       |
| *Scolopsis lineata*                | +          |          |         |
| **PHEMPHERIDIDAE**                 |            |          |         |
| *Pempheris vanicolensis*           | +          | +        | +       |
| **POMACANTHIDAE**                  |            |          |         |
| *Chaetodonoplus melanosoma*        | +          |          |         |
| *Chaetodonoplus mesoleucus*        | +          | +        | +       |
| **POMACENTRIDAE**                  |            |          |         |
| *Abudedefa sexfasciatus*           | +          | +        | ++      |
| *Abudedefa vaigiensis*             | +          |          | +       |
| *Amblyglyphidodon aureus*          | +          |          |         |
| *Amblyglyphidodon batunai*         | +          |          |         |
| *Amblyglyphidodon curacao*          | ++         | ++       | ++      |
| *Amblyglyphidodon leucogaster*     | +          |          | +       |
| *Amphiprion clarkii*               | +          |          |         |
| *Chromis amboinensis*              | +          |          |         |
| *Chromis ternetensis*              | +          |          |         |
| *Chromis viridis*                  | +          |          |         |
| *Chromis xanthura*                 | +          |          |         |
| *Chrysiptera caeruleolineata*      | +          |          |         |
| *Chrysiptera rolandi*              | +          | +        | +       |
| *Chrysiptera talboti*              | +          |          |         |
| *Dascyllus trimaculatus*           | +          |          |         |
| *Dischistodus perspiciatus*        | +          | +        | +       |
| *Dischistodus prosopotaenia*       | +          |          | +       |
| *Hemi glyphi donon plagiometopon*   | +          |          | +       |
| *Neo glyphi donon curacao*         | +          |          | +       |
| *Neo glyphi donon melas*           | +          | +        | +       |
| *Neo glyphi donon nigrioris*       | +          | +        | +       |
Fish species |
|-----------------|
| Neoglyphidodon thoracotaeniatus + |
| Neopomacentrus anabatoides + |
| Neopomacentrus azysron + |
| Plectroglyphidodon lacrymatus ++ |
| Pomacentrus alexanderae +++ |
| Pomacentrus amboinensis + |
| Pomacentrus auriventeris + |
| Pomacentrus cuneatus + |
| Pomacentrus grammorhynchus + |
| Pomacentrus javanicus ++ |
| Pomacentrus lepidogenys + |
| Pomacentrus melanochir + |
| Pomacentrus moluccensis ++ |
| Pomacentrus philippinus + |
| Pomacentrus smithi +++ |
| Neopomacentrus azysron + |
| Neopomacentrus anabatoides + |
| Neopomacentrus cuneatus + |
| Neopomacentrus grammorhynchus + |
| Neopomacentrus javanicus + |
| Neopomacentrus lepidogenys + |
| Neopomacentrus melanochir + |
| Neopomacentrus moluccensis ++ |
| Neopomacentrus philippinus + |
| Neopomacentrus smithi +++ |
| Pomacentrus amboinensis + |
| Pomacentrus aureiventris + |
| Pomacentrus cuneatus + |
| Pomacentrus grammorhynchus + |
| Pomacentrus javanicus + |
| Pomacentrus lepidogenys + |
| Pomacentrus melanochir + |
| Pomacentrus moluccensis ++ |
| Pomacentrus philippinus + |
| Pomacentrus smithi +++ |

The reef types at all study sites were characterized by being a reef slope, with variation of benthic substrate. The highest percentage of hard coral cover was encountered at Pelangi Island (65.66±0.09%), yet it created a more homogeneous benthic coverage and indirectly affected the richness of reef fish species related to food availability [4], whilst the other sites have various benthic coverage that could escalate the reef fish species diversity. Dead coral with algae found higher in Papatheo (21.41±0.02) and also dead coral found on Sepa Besar (14.88±0.02) (table 2).

Table 2. Benthic cover in all study sites.

| Benthic | Study Sites |
|---------|-------------|
|         | Sepa Besar (%) | Papatheo (%) | Pelangi (%) |
| Hard coral | 44.23±0.04 | 40.39±0.07 | 65.66±0.09 |
| Dead coral with algae | 21.41±0.02 | 42.42±0.09 | 17.92±0.02 |
| Abiotic | 15.88±0.01 | 16.02±0.15 | 13.93±0.05 |
| Dead coral | 14.88±0.02 | 0.00 | 0.02±0.01 |
| Other | 1.78±0.01 | 1.17±0.01 | 1.66±0.01 |
| Algae | 1.49±0.01 | 0.00 | 0.61±0.01 |
| Soft coral | 0.33±0.01 | 0.00 | 0.00 |

Percentage of hard coral covers at Pelangi Island was the highest compared to the other islands. However, in terms of reef fish abundance and species richness, Pelangi Island was the lowest of all islands. Reef fish presence in the ecosystem is known to depend on coral health, indicated by the
percentage of live coral covers [4]. A plausible explanation for the low abundance and species richness of reef fish at the Pelangi Island is that preferences for specific morphological types of coral can determine the occurrence of reef fishes [31]. In the present study, massive coral formations were found almost exclusively at Pelangi Island whilst the morphological type of corals at Sepa Besar and Papatheo Island were more varied.

The presence of reef fish was positively related to the abundance of their preferred food items [33]. Pomacentridae was the most abundant species. Most of these species at all study sites were herbivorous fish (algae-eater). In addition, Pomacentridae are highly influenced by morphological characteristics of substrate, even specific species of Pomacentridae tend to use coral reefs as habitat rather than food resources [34]. Still, the correlation between them were not habitually positive [35, 36].

Based on trophic groups, there were 7 reef fish trophic groups found on the islands, namely benthic invertivore, corallivore, carnivore, detritivore, herbivore, omnivore and planktivore. The group of benthic invertivore reef fish (benthic invertebrates consumer) includes reef fish species from the families Holocentridae, Labridae, Pomacentridae, and Chaetodontidae. The Thecorallivore group (coral polyps consumer) consists of reef fish species from the families Chaetodontidae and Labridae. The carnivore group (meat consumer) includes reef fish species from family Apogonidae, Labridae, Nemipteridae, Lutjanidae, Muraenidae, Serranidae, and Carangidae. Reef fish species from the detritivore group (organic matter consumers) were represented by only one species in Sepa Besar island which is *Parupeneus macronema* (Mullidae). The herbivore group (algae consumers) includes reef fish species from family Ephippidae, Pomacanthidae, Scaridae and Siganidae. The group of omnivore fish (natural feed variation consumers) includes reef fish species from the families Pomacanthidae and Pomacentridae. The planktivore group (plankton consumers) includes reef fish species from the family Apogonidae, Blenniidae, Caesionidae, Labridae, Phempherididae, Pomacentridae, Centriscidae, Holocentridae, and Serranidae.

Sepa Besar Island has the highest species richness and abundance of trophic group benthic invertivore, Papatheo Island has the highest abundance of omnivore trophic group and Pelangi Island the highest trophic group consisting of carnivore with 8 species and herbivore with 9 species (figure 4) but highest abundance of corallivore fishes (figure 5). Functional group abundance has been found in many studies not related with reef fish species richness based on the trophical group [10, 37, 38]. A better comparison can be shown in nMDS (figure 6) at the transect level, that shows that Papatheo and Pelangi Island to group, which means those islands have similar reef fish communities. Different reef fish composition and abundances provide strong visual support for the way these groups are clearly seperated between Sepa Besar than the other sites.

Reef fish from carnivorous group are known from other studies to increase the abundance towards more exposed areas [33]. Pelangi Island is more exposed to currents. Papatheo and Pelangi Island has the highest dead coral with algae cover, which induces higher abundance of herbivorous fish. This is also observed in the previous research [39]. Higher species richness of herbivore group should benefit reefs because of the variety of feeding behavior, decreasing the probability that any given algae will overgrow the healthy coral reef [40, 41]. In addition, Pelangi Island also has high abundance of herbivorous reef fish as well as high species richness of the herbivore group which related with less dead coral with algae. Large herbivores’ feeding activity could reduce algae biomass [42, 43] and usually, escalate the coral cover [44]. Omnivore and planktivore groups are the dominant trophic structure of all sites that could contribute to more reef fish species and abundance for overall species richness and abundances in all study sites.
Figure 4. Reef fish species richness based on trophical group in all study sites (a) benthic invertivore; (b) corallivore; (c) carnivore; (d) detritivore; (e) herbivore; (f) omnivore; (g) planktivore.
Figure 5. Reef fish abundance based on tropical group in the study sites (a) benthic invertivore; (b) corallivore; (c) carnivore; (d) detritivore; (e) herbivore; (f) omnivore; (g) plantivore.
Figure 6. Non-metric Multidimensional Scaling (MDS) plot of fish communities in all study sites showing pattern of association among 120 species based on abundances.

The corallivore group abundance in relation to hard coral cover showed a positive correlation ($R^2 = 0.7786$) (figure 7). It is not surprising that the high coral cover is associated with the high abundance of corallivore in coral reef ecosystems. Corallivore groups of reef fish have the most apparent and direct reliance on living hard corals [45, 46]. What is important to note is that in all study sites, the abundance of corallivorous groups is still appropriate to the total hard coral cover, meaning that the coral cover is not affected by the corallivores as its predator. This is important because under some conditions, effects of corallivores on habitat-forming corals and the hard corals in the ecosystems are generally considered to be damaging and reducing growth of living hard corals [47, 48].

Figure 7. Correlation between abundance of corallivore group and hard coral cover.

4. Conclusion

The abundance of reef fish in Sepa Besar Island, Pelangi Island and Papatheo Island was positively related to the availability of their food, but Sepa Besar has different characteristics with other islands based on reef fish composition and abundances. Omnivores and Herbivores are the highest contributor for overall species richness and abundances on all study sites. Corallivores have a positive effect to the coral reefs. Yet, there are various effects that could affect the coral reefs aside from the corallivores.
Further studies need to be conducted in other islands in the Kepulauan Seribu to investigate the overall picture of the archipelago. It would also be important to combine data with environmental assessments from southern and northern Kepulauan Seribu to assess the effect of the water quality gradient on Corallivores and reef fish compositions, to see the gradient effect of the water condition across the archipelago through coral cover and relate it with corallivorous circumstances.

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