The Influence of coral reef benthic conditions on associated fish assemblages around Puruf Island Water, Cenderawasih Bay, Papua, Indonesia

ABSTRACT

Coral substrate in lifeforms is an environmental aspect significantly affecting fish in the ecosystem. The conditions of these coral lifeforms greatly determine fish associations and distribution. Therefore, this study aimed to explore the effect of coral reef benthic conditions on associated with fish assemblages. Thisresearch used monitoring data in 2018. Coral data was taken using transect intercept points for corals, visual census data for coral fish, which were classified into functional fish (herbivores) and key fish species for coral fisheries (carnivores).The data had been analyzed by using principal component analysis and hierarchical classification. The results showed that there was a strong interaction between fish and coral lifeforms. The interactions occurring were more varied in space and time, which affected the composition of fish community, and the spatial pattern in coral reef ecosystem. Changes in coral lifeforms and live cover had the potential to limit reef fish populations. Furthermore, the presence of herbivore and carnivore fish was proportional in coral reef ecosystem.The future research challenge is to formulate the policies needed to maintain the condition of coral reefs as a whole

Keywords: coral reef, benthic, reef fish, Cenderawasih bay, herbivore, carnivore.

1. INTRODUCTION

Indonesia is characterized by coral reef covering 39,538 km^2, equivalent to 16% of the total global reef location, and is recognized as the most diverse ecosystem (1). Despite the relative abundance, this ecosystem has been severely damaged by anthropogenic factors, including local stressors such as pollution, eutrophication, overfishing, destructive fishing practices, and mass bleaching associated with climate change (2,3). Approximately a quarter of Indonesia's 270 million population lives on the coast in 30 km of coral reef, constituting the largest human population associated with coral reefs. Due to the high concentration, more than 95% of coral reefare susceptible to threats due to overfishing and destructive fishing (1,2).

Among the concentration locations in Indonesia, Cenderawasih Bay National Park (TNTC) is the largest national park, comprising 460 coral species consisting of 67 genera and subgenera, with 260 species of Scleractinia along the coast. Other species consisted of 201 mollusks, 17 mangrove vegetation, 9 coastal forest vegetation, 35 terrestrial forest vegetation, 7 seagrass, 184 birds, 14 mammals, and 17 reptiles (4). Coral reef ecosystem is mostly found in Cenderawasih Bay National Park, consisting of fish which are important components. However, population growth and the rising economic needs of the community

have caused excessive fishing efforts(5–8). This has led to the disruption of marine resources sustainability including coral reef (9).

The ability of ecosystem to recover from degradation is hampered by increasing frequency, intensity, and variety of disturbances(10–12). Coral reef degradation caused by increasing anthropogenic pressures (fisheries exploitation, pollution) and climate change is higher compared to natural disturbances (cyclones) (13–16). This causes a decrease in coral cover and structural complexity(17,18), associated changes in coral and fish community composition(17,19) as well as shifts in the dominant benthic biota (20–24).

The shifts recorded on coral reef include changes in coralline, sponge, or most commonly benthic macroalgae dominance (22,23). However, other benthic lifeforms are a typical component of most scleractinian coral. This is due to their primary function as providers of complex structural habitats and responsible for the high diversity of reef-associated organisms, providing various important ecosystem services such as food resources (25–27).

All major coral reef locations globally have experienced a decrease in coral cover(18,28,29). In this context, reduced coral cover is indicative of an increasing shift in dominant benthic biota(23), and changes in benthic community composition (30). The shift from corals to macroalgae can lead to excessive herbivore fish populations and stimulate fisheries. However, the impact of benthic community on coral lifeforms, including the entire ecosystem, and assemblage of reef fish (herbivore and carnivore) is not fully understood.

The complex interconnections between organisms and their benthic substrates (coral lifeforms) imply that changes in one aspect of ecosystem can lead to a cascade of subsequent which are often unanticipated (31–33). A previous study has shown a strong relationship between coral reef fish and benthic habitats (34,35). There is variability in the specific responses of different fish, causing significant changes in coral cover (36–38). For example, the loss of live coral can cause shifts in entire fish assemblages (36,39–41), as well as a rapid decrease in fish abundance and diversity (42–44). Although the potential of benthic habitats to provide the environments required for reef fish had not been extensively explored, (45) showed that soft coral was unfavorable a substitute for hard types. From ecosystem perspective, some fish species can associate with the same or different habitats based on community by providing the environments required for associated reef fish assemblages. Based on the description, this study aimed to explore the impact of coral reef benthic conditions on associated with fish assemblages.

2. MATERIAL AND METHODS

2.1Location and Time

This study was conducted from July to September 2024, at Rumberpon and Wamesa Districts, Wondama Regency, as shown in Figure 1. The location was part of Cenderawasih Bay National Park (4), which consists of three locations (Puruf, Nuana and Tapapai Island). Puruf Island is larger than the other two islands, and is an island for tourist destinations.

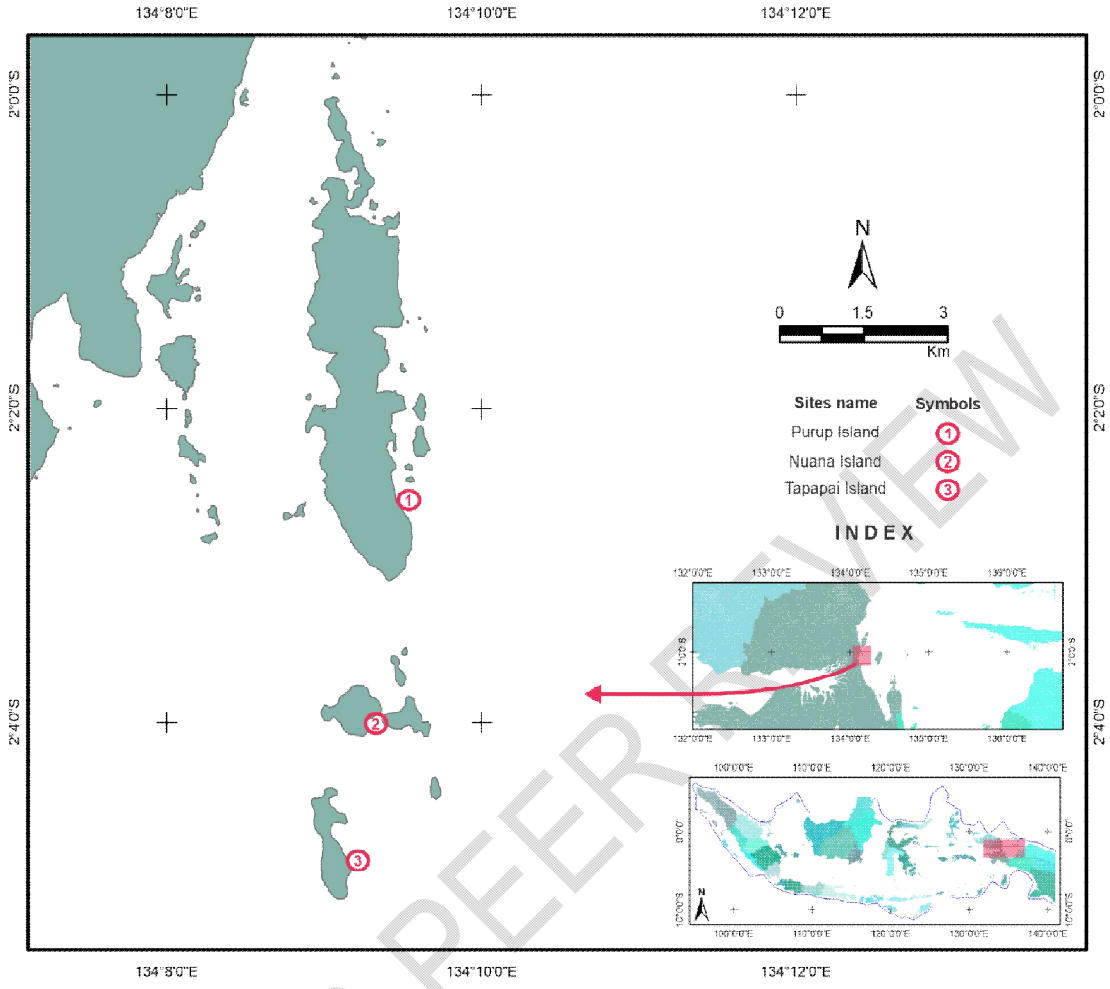


Figure 1. Study Location Map

2.2 Data Collection Method

The data used were obtained from Reef Health Monitoring database conducted by Bird Head Seascape (BHS) Papua Consortium, stored at the Research and Community Service Institute, University of Papua, Manowari, Indonesia. The data used is observation data in 2018.Coral data was collected using Point Intercept Transect (PIT) method (46,47) to determine the basic biota constituting coral reef ecosystem. Observations were made using lifeforms category or growth providing a morphological description of coral reef ecosystem (48). PIT method only monitored coral lifeforms by collecting reef data per point along the transect.

2.3 Data Analysis

The total percentage of coral cover and benthic growth forms are presented in graphs and tables using Excel. The calculation of the percentage of cover for each component was carried out using the formula expressed in studies (49). Subsequently, the condition of coral reef cover was divided into five categories, according to a previous study (48), comprising very poor (0 - 10%), poor (11 - 30%), moderate (31 - 50%), good (51 - 75%), and very good

(76 - 100%). Analysis of location grouping based on coral lifeforms types was carried out using cluster analysis.

Fish species abundance and estimated length were assessed using bottom visual sensors (47). Based on the results, species recorded were the families/subfamilies Acanthuridae, Carangidae, Carcharinidae, Dasyatidae, Haemulidae, Lethrinidae, Lutjanidae, Scaridae, Scrombidae, Serranidae, Siganidae, and Cheilinus undulatus. The total fish biomass recorded included high-value fish species (families Serranidae, Lutjanidae, Lethrinidae, and Haemulidae). These species were classified as carnivore, and the biomass of herbivore fish (families/subfamilies Acanthuridae, Scaridae, and Siganidae) was calculated to determine the status of coral reef.

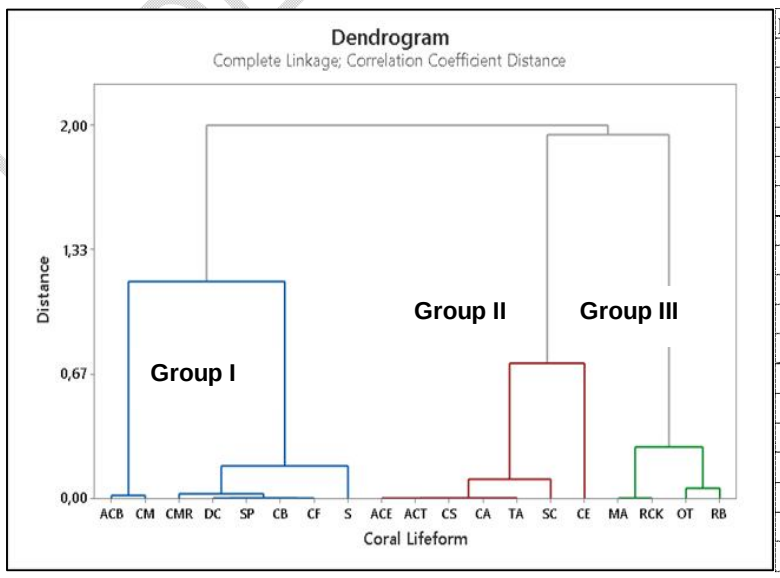
2.3 Data Analysis

Principal component analysis (PCA) was used to describe the characteristics of coral reef fish habitats (50). The results were confirmed by cluster analysis to ensure the grouping of coral reef fish habitats based on coral lifeforms types. Cluster analysis was also used to describe the spatial distribution of coral reef fish based on lifeforms (50).

3. RESULTS AND DISCUSSION

3.1 Habitat Characteristics Based on Coral Lifeforms

Habitat characteristics search of study locations based on coral lifeforms types showed significant grouping, as presented in Figure 2. Group 1 was characterized by Acropora branching, coral massive, coral mushroom, dead coral, sponge, coral branching, coral foliose, and sand. Meanwhile, group II had coral lifeforms Acropora encrusting, coral submassive, coralline algae, turf algae, and soft coral, as well as coral encrusting. Group III consisted of macroalgae, rock, OT, and Ruble. Regarding the proportion of coral lifeforms, further observation showed that group III had similar characteristics to Nuana Island location. The characteristics of group II were identical to Tapapai location and group I had Puruf Island group habitat (Figure 2).In general, the research location was characterized by the type of coral lifeform from massive, foliose, branching and soft corals. Coral fragments (rubble) occupies a high portion as an abiotic factor (Figure 3).



Lifeform Codes	Remarks
ACB	Acropora branching
ACE	Acropora encrusting
CB	Coral branching
CE	Coral encrusting
CF	Coral foliose
CM	Coral massive
CS	Coral submassive
CMR	Coral mushroom
SC	Soft coral
SP	Sponge
OT	Other
CA	Crustose coraline algae
MA	Macro algae
TA	Turf algae
S	Sand
RB	Rubble
RCK	Rock
DC	Dead coral

Figure 2. Grouping of coral lifeforms characteristics based on study location.

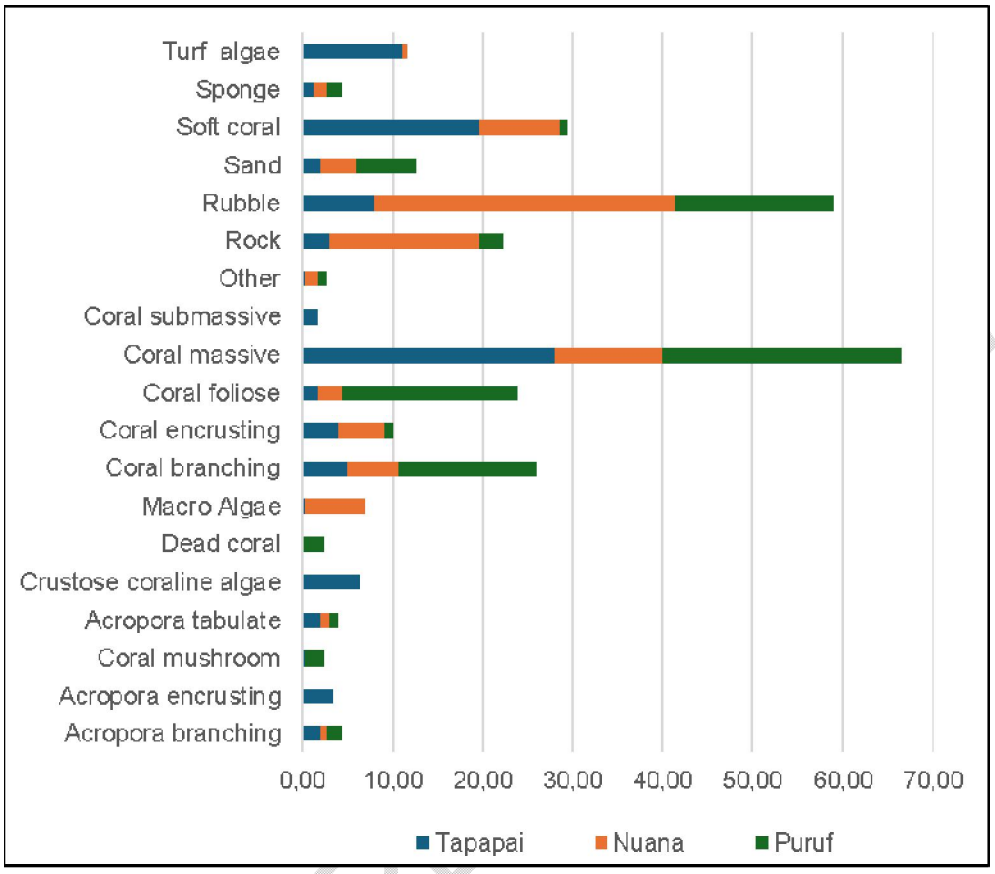


Figure 3. Proportion of coral lifeforms at the study location

The influence of coral habitat characteristics in lifeforms on the interaction and distribution patterns of fish (herbivore and carnivore) showed a strong interaction. The interaction varied in space and time due to the significant influence on composition of fish community and the spatial pattern of target fish in coral reef ecosystem. Changes in coral lifeforms and live cover had the potential to limit reef fish populations(51–54)including Indonesia (30,55).The condition of coral reef cover was divided into five categories, according to English et al. (1994).These consisted of very poor (0-10%), poor (11-30%), moderate (31-50%), good (51-75%), and very good (76-100%). Analysis of location grouping based on coral lifeforms was carried out using cluster analysis. The results showed that coral reef condition of Puruf, Tapapai, and Nuana Island belonged to the good, poor, and moderate categories, respectively (Table 1).

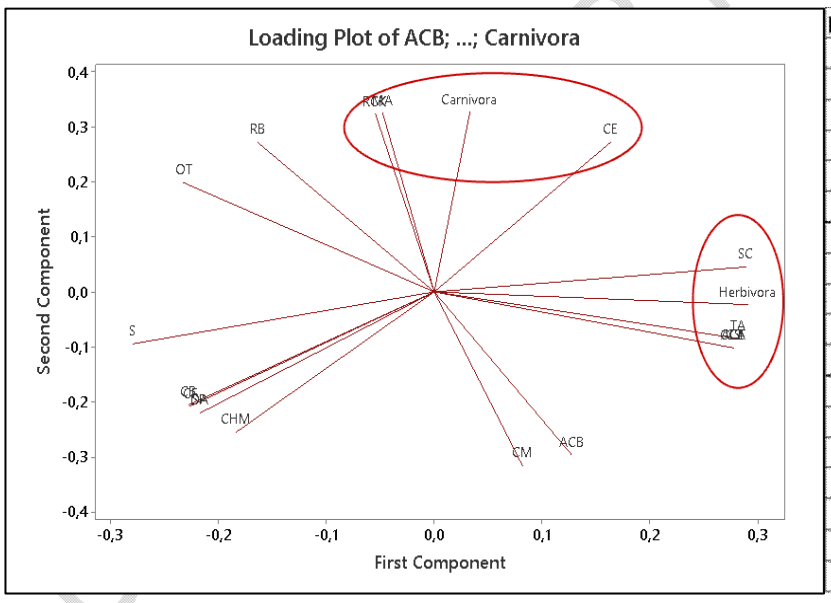
Table 1. Coral conditions on selected sites

Location Name	Hard coral (%))	Categories according to English et al. (1994)
Tapapai Island	48	Moderate
Nuana Island	27	Poor
Purup Island	67.33	Good

The results showed that Purup Island had a higher percentage of live coral cover compared to the study by (56), although Cenderwasih Bay obtained values of 47% and 44%, respectively. This study was approximately similar to the Tapapai coral cover which was categorized as moderate. The results indicated that the quality of coral reef was in poor and good conditions, but could be considered good. Some of coral was damaged (15%) due to pressure from human activities using environmentally unfriendly fishing gear and natural phenomena such as earthquakes and waves.

3.2 Associated Fish and Coral Lifeforms

The analysis results showed that there was association between coral lifeforms as well as the presence of herbivore and carnivore fish, as presented in Figure 4. Generally, carnivore is more associated with coral encrusting, branching, and rock, while herbivore is related to soft coral, macroalgae, and turf algae. This association supported previous analysis conducted in Cenderawasih Bay location (30), where coral reef conditions had a close relationship with fish (57–60). In addition to the cover of live coral, the presence of reef fish was also related to coral lifeforms (61–63). Target fish groups often experience a decrease in population after major disturbances(64,65). Moreover, several studies have shown the importance of coral habitat in supporting reef fish groups and promoting their distribution (30,53).



Lifeform Codes	Remarks
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Figure 4. Grouping of associated herbivore and carnivore fish with coral lifeform types.

The presence of herbivore fish in coral reef ecosystem plays a significant role as a cleaner of algae that sticks to living and dead coral. By eating algae and turf, herbivore fish regulate the stability of coral ecosystem (46), ranking second at the tropical level as first-level consumers. Meanwhile, carnivore fish describe the condition of coral reef ecosystem. This group of fish is the target of fishing due to the high selling price, leading to elevated intensity of fishing activities.

The analysis results showed that the biomass of herbivore fish at the three observation locations was very different, as shown in Table 2. Herbivore fish at Purup Island location were lower compared to others (Tapapai and Nuana Island). This was related to the level of fishing at the existing location, where the intensity was greater at Purup Island and two other locations. The identified groups were from Achanturidae (sand skin), Scaridae (old parrotfish), Siganidae (baronang), and Labridae (napoleon/maming) families. This type of fish was often caught by local fishermen, particularly from Yomakan community.

Similar to herbivore group, carnivore fish shows the same biomass, which is lower at Purup Island compared to others (Tapapai and Nuana Island). Carnivore group consists of fish from Lutjanidae (snapper), Letrinidae (lencam), and Seranidae (grouper) families, serving as target of local fishermen.

Table 2. Herbivore and carnivore reef fish of selected sites

Location Name	Herbivore Fish (kg/ha)	Carnivore Fish (kg/ha)
Tapapai	316.86	38.24
Nuana Island	128.21	90.67
Purup Island	64.84	13.18

Based on the existing biomass, both herbivore and carnivore groups, describe their presence proportionally in the three study locations. This shows that the predominance presence of herbivore group a location needs to be followed by thecorresponding amount of carnivore and vice versa. Therefore, the condition of coral reef ecosystem and the oceanographic aspects of water will support fish stability.This findingwas not too surprising because the same research results were also found by other researchers (66).

Although habitat preferences may initially determine the spatial distribution of many reef fish, the patterns that are formed can be altered by several ecological processes, including mortality, competition, and fish behavior(67–70). This is particularly relevant for target fish due to the lack of further movement after being established. Many fish species have very small home ranges, along with high fidelity to specific fishing sites (71–73). Moreover, the regulation of target fish in coral reef ecosystem is strongly influenced by trophic level structure, feeding patterns, the degree of habitat disturbance, and fishing activity (51,52,74,75).

4. CONCLUSION

The association of fish and coral is largely determined by the characteristics of the benthic substrate (lifefom). This character is important in influencing the spatial distribution of coral fish based on coral lifeform. Herbivorous and carnivorous fish are proportional in number and type based on the characteristics of the coral lifeform.

CONSENT

Informed consent was obtained from all participants prior to data collection, ensuring that they were aware of the purpose of the study and their rights as participants. Confidentiality

was maintained throughout the study, and participants were assured that their responses would be anonymized in any reports or publications

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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