

Coral-fish association and its spatial distribution in Cenderawasih Bay National Park Papua, Indonesia

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Abstract. Spatial distribution of coral fish is related to the preferences of habitat utilization, and the ecological processes which form the associative relationship between coral reef and fish in certain area. There were 17 research stations set up in the coral reef ecosystem of Cenderawasih Bay National Park for revealing the coral-fish association and its spatial distribution. The coral data were collected by the line intercept transects, while fish data collected by underwater visual census. Based on the Principal Component Analysis, the study showed that the habitat of coral reef ecosystems were characterized by life coral, dead coral, abiotic factors, algae, and other fauna (*zoanthid*, sea fans). Spatial distribution of the fish at several research stations was strongly determined by the dead corals, other fauna, mortality index of corals, algae, and abiotic factors. Furthermore correspondent analysis grouped the association between the research stations and the fish species into several categories based on the research station. The distribution of several fishes i.e. *Caesio lunaris*, *Pterocaesio bananas*, *Pterocaesio digamma*, *Lutjanus biguttatus*, *Monotaxis grandoculis*, *Siganus guttatus*, *Zebrasoma scopas*, *Parupeneus barberinus*, *Parupeneus multifasciatus*, *Cephalopholis cyanostigma*, *Lutjanus fulvus* and *Siganus vulpinus*, might widely spread. These species were found at several research stations.

Key Words: coral-fish association, coral fish distribution, coral reef ecosystem, CBNP.

Introduction. Cenderawasih Bay National Park (CBNP) is the largest national park in Indonesia. The national park contains 460 coral species which consists of 67 genera and sub genera, 260 Scleractinia species which distribute at the seashore of the islands, other species consists of 201 molluscs species, 17 species of mangrove vegetation, 9 species of coastal forest vegetation, 35 species of terrestrial forest vegetation, 7 seagrass species, 184 species of birds, 14 species of mammals and 17 species of reptiles (CII, TNC, BBTNTC, UNIPA 2006).

Coral reef ecosystems are predominantly found in CBNP region, where coral fishes are important components in the ecosystems (Allen 2006). Nevertheless, human population growth and the encouragement of the economic needs of the people in the CBNP region cause marine overfishing effort. The result is the preservation of marine resources including coral reefs in the region to be disrupted and would affect the sustainability of fish resources in the region. This problem is similar to that found in the South-East Aru Conservation Region (Dangeubun & Tetelepta 2013).

In order to ensure the sustainability of reef fish resources in the region, it is necessary to develop appropriate management strategies. For this purpose, information about the structure and distribution of coral reef fish communities in the region is needed. The processes determining the structure of the coral fish represent the most important aspect to be considered (Williams 1991). To understand the processes, firstly accurate estimation of the distribution and abundance of the fish must be done, for instances the estimation of distribution and abundance on time and space scale (Fowler 1990), and of discontinuous distribution on a large scale between corals (Williams & Hatcher 1983). Several studies have shown that the exposed coral influenced the fish

distribution (Floeter et al 2007), coral life-form (Bawole et al 1999; Hukom & Bawole 1999), and fish movement at day and night (Nagelkerken et al 2000), and back-reef habitat and lagoon (Adams & Ebersole 2002).

The patterns of distribution scale and the abundance of coral fish, however, are very little known (Green 1996) and depend on the specific characteristics of coral reef ecosystem. Distribution of adult coral fish were closely related to the recruitment process (Williams 1991), whereas the recruitment patterns of coral fish are associated with the ontogenetic movement of fish during the period of its life cycle (Lecchini & Galzin 2005); spatial and temporal variation, with relation to the size of micro-habitats (Dahlgren & Eggleston 2001), and with the species interaction at different contour of coral reefs (Almany 2004; Jones 2007). Coral fish population structure and distribution has a unique pattern and could be specialized based on the habitat characteristics. Therefore, the fish population structure and distribution could be different among the sites. These are due to the habitat utilization preferences and ecological processes. The purpose of this study is to reveal the spatial distribution scale and the abundance of the fish among sites in CBNP, and to determine the habitat characteristics of the fish associated with the physical and biological characteristics of coral reef benthic community.

Material and Method. The fieldwork was done on June-August 2012, in the CBNP Papua (Figure 1). Mapping of coral reef distribution was done based on the interpretation of Landsat 7 ETM+ and used to determined the observation sites which is located side by side of WWF and CII research sites of 2006.

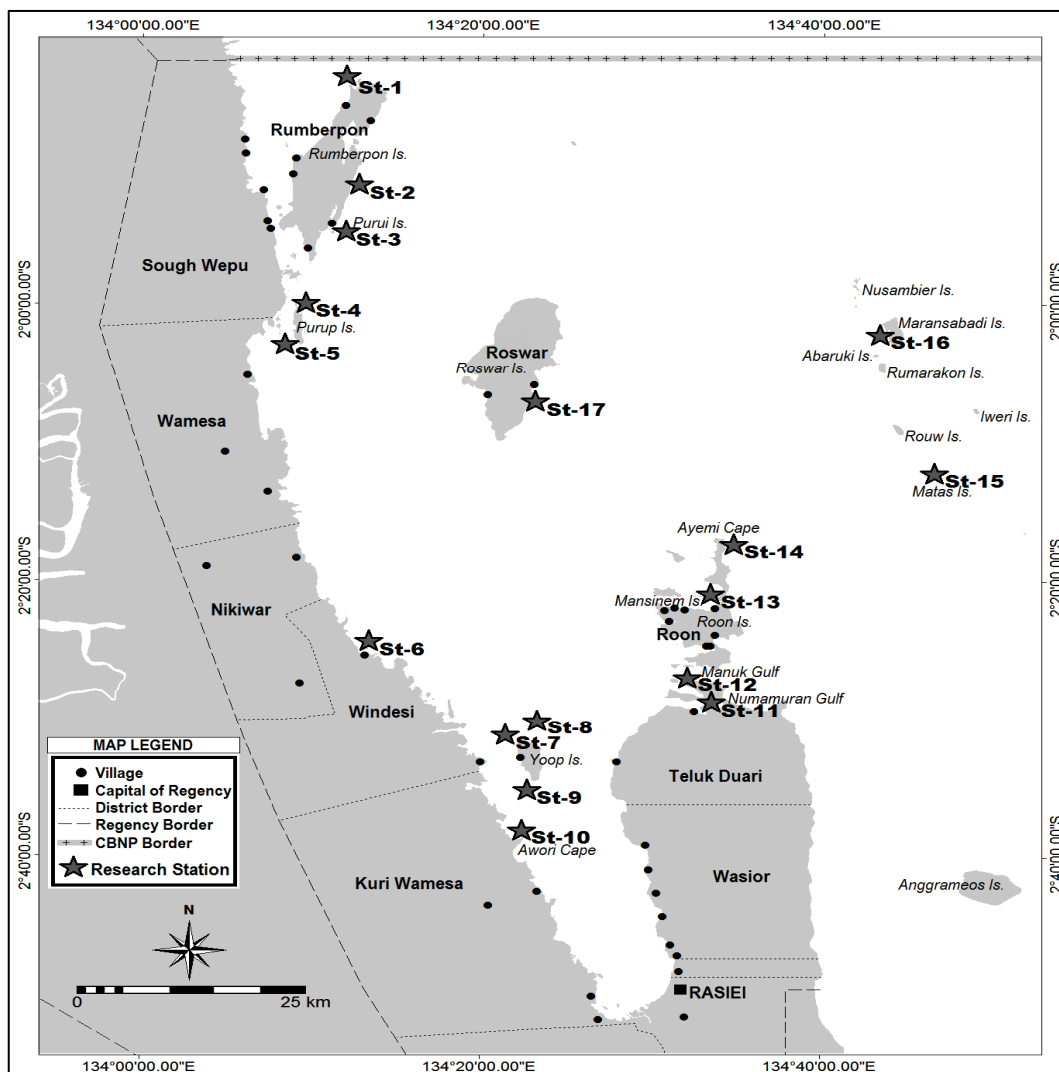


Figure 1. Location of study site, with sampling points.

There were 17 selected research stations set up in the coral reef ecosystem: 1 = North Rumberpon; 2 = East Rumberpon; 3 = Purui; 4 = West Purup; 5 = Southeast Purup; 6 = Windesi; 7 = Northwest Yoop; 8 = Northeast Yoop; 9 = South Yoop; 10 = Awori Cape; 11 = Numamuran Gulf; 12 = Manuk Gulf; 13 = Mansinem; 14 = Ayemi Cape; 15 = Matas; 16 = Maransabadi; 17 = Roswar (Figure 1). Coral lifeform data were collected at the depth of 3-15 m using Line Intercept Transect (LIT) method (English et al 1997) with some modifications. Observations were done at the depth of 10 m along the transect lines and repeated 3 times. Technical implementation in the field, the diver was set up a tape along 70 m parallel to the shoreline where the position of coastal is on the left of diver. Then, LIT was set up on transect lines at the depth of 0-10 m, 30-40 m and 60-70 m. All biota and substrates found under the transect line were recorded with the accuracy within centimeters. Those data were used for calculating cover percentage value for each category of biota, coral species and substrate types.

The method of Underwater Visual Census (UVC) was used for fish data collection. The diver counted the actual numbers of target species seen within 2.5 metres on either side along 70 m transect. The total observation area of each transect was 350 m². Identification of coral fish species was done using the guidance of Kuiter (1992) and Lieske & Myers (1994). The fish species were grouped into three main groups (English et al 1997).

Characteristics of coral reef conditions were determined using multivariate statistical analysis based on Principal Component Analysis (PCA) (following Ludwig & Reynolds 1988; Digby & Kempton 1987). Association between coral reef condition characteristics and coral fish were determined using Factorial Correspondent Analysis (FCA) (following Legendre & Legendre 1983).

Results and Discussion

Characteristics of coral ecosystems. PCA was used to evaluate habitat characteristics of coral reef ecosystems. Six main variables of habitat characteristics were used to distinguish the coral reefs between research stations. The PCA results showed that there were three components influencing the coral reef condition. These explained 88% of the total variance (Figure 2). Thus only about 12% of coral reef ecosystem characteristics were explained by other factors (outside of the 6 variables). The first components, second and third respectively explained 50% (root traits 3.03), 21% (root traits 1.3) and 17% (root traits 0.99).

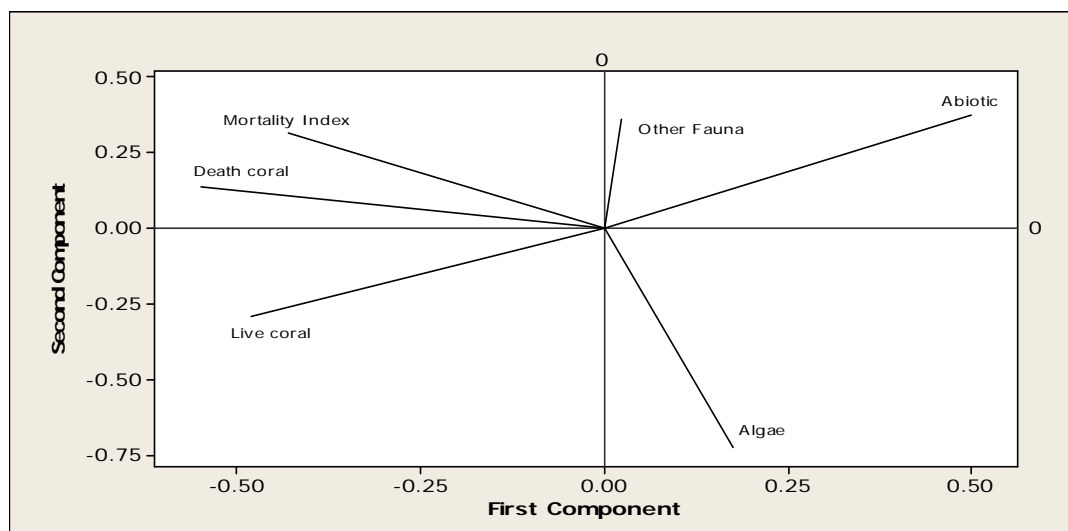


Figure 2. The result of Principal Component Analysis showing habitat characteristics of coral reef ecosystem.

The first component was characterized by coral lifeform, dead coral and abiotic factors. The second component was characterized by algae, and the third component was characterized by algae and other fauna (zoanthid, sea fans). Interesting fact is that the

variable of coral mortality index was not included as a variable in the three main components. This indicated that the rate of dead coral was not spread to all observation stations.

There are two main factors controlling the formation of coral lifeform, i.e. the condition of coral reef and research station position to the hydrodynamic conditions of the waters. Coral reefs with good condition were commonly found at research stations which are located relatively shielded from the hydrodynamic effects. On the other hand, reef with bad-middle condition are commonly found at research stations located more open to hydrodynamic effects. It is similar to the result of a research done by Bozec et al (2005) in New Caledonia to explain fish-habitat association on disturb coral reefs. Based on their observation, in areas of Sainte-Marie Bay where wave action and wind exposure were reduced, large branching *Acropora* spp. form dense coral-beds. By contrast, at the entrance of Sainte-Marie Bay, a mixed coverage of massive and incrusting corals, small branching corals and brown algae dominated.

PCA grouped the research stations based on their habitat characteristic, i.e. Group I was a North group of research stations (Rumberpon Island, Manu Bay, South part of Yoop Island, Aiwori Cape, Southeast part of Purup Island, Northeast part of Purup Island, Mansinem Island, Ayemi Cape, Northwest part of Yoop Island, Purui Island and Roswar Island). This group was primarily characterized by live coral. Group II was an East group of research stations (Rumberpon Island, Maransabadi Island and Matas Island). These area was characterized by dead coral, algae and other fauna. Group III included Windes, Northeast part of Yoop Island and Numamuran Gulf, which was characterized by abiotic factors .

PCA with the hierarchy analysis confirmed a similar result (Figure 3). Cutting point (final partition) at a 93% similarity distance grouped observation stations into three groups, and the habitat characteristics of the coral reef ecosystem at the fusion point of 73% from the similarity distance index. Group I was characterized by coral lifeforms, group II - by dead coral, other fauna, coral and algae mortality index, and group III - by abiotic factors.

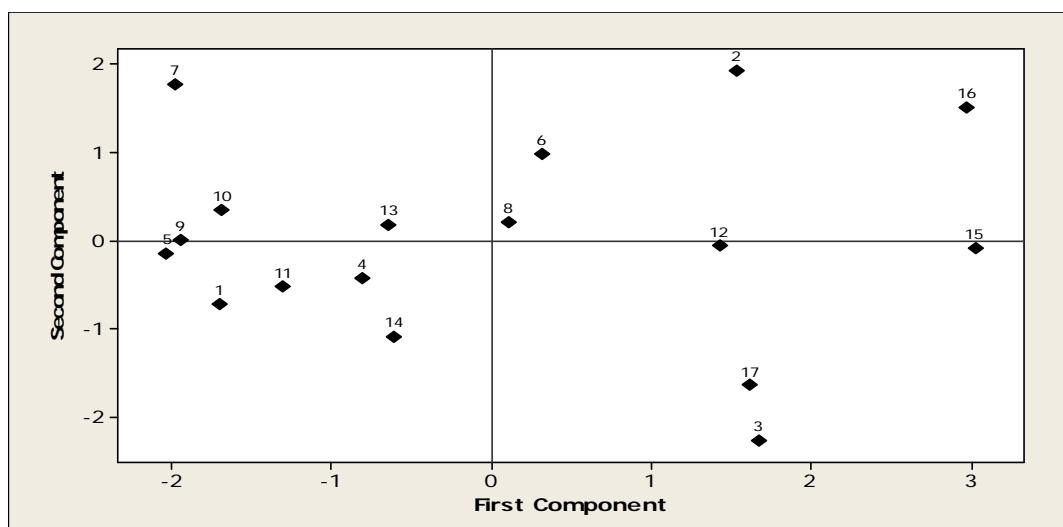


Figure 3. The result of Principal Component Analysis showing distribution of research station (♦ = research station; 1 = North Rumberpon; 2 = East Rumberpon; 3 = Purui; 4 = West Purup; 5 = Southeast Purup; 6 = Windesi; 7 = Northwest Yoop; 8 = Northeast Yoop; 9 = South Yoop; 10 = Awori Cape; 11 = Numamuran Gulf; 12 = Manuk Gulf; 13 = Mansinem; 14 = Ayemi Cape; 15 = Matas; 16 = Maransabadi; 17 = Roswar).

Spatial distribution of fish. Correspondence analysis illustrated the association among the characteristics of the research stations, which explained 90.29% of the total variance with inertia of the first component of 0.0798 (72.87%) and the second component of 0.0798 (17.42%). The analysis grouped the association between research stations and economical valued of fish species into five groups (Table 1, Figure 4).

Table 1

Species list of target fish and its distribution at sampling location

No.	Fish species	Family	Sampling station	Group
1	<i>Caesio cuning</i>	Caesionidae	1,3,4,5,6,9,12,14,15,17	I
2	<i>Pterocaesio pisang</i>	Caesionidae	1,6,7,8,9,11,12,13,14, 16,17	II
3	<i>Ctenochaetus striatus</i>	Acanthuridae	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15, 16,17	II
4	<i>Caesio lunaris</i>	Caesionidae	1,7,8,14	II
5	<i>Acanthurus pyroferus</i>	Acanthuridae	1,2,3,4,5,6,7,9,10,13, 14,15,16,17	II
6	<i>Pterocaesio digramma</i>	Caesionidae	3,4,14,16	II
7	<i>Lutjanus biguttatus</i>	Lutjanidae	3,4,5,6,9,10,12,13,14, 15	II
8	<i>Monotaxis grandoculis</i>	Lethrinidae	1,3,4,5,6,8,10,12,13, 14,15,17	II
9	<i>Siganus guttatus</i>	Siganidae	1,3,6,9,10,13,14,15	II
10	<i>Zebrasoma scopas</i>	Acanthuridae	1,2,4,5,6,7,8,9,11,12,13,14,15,16,17	II
11	<i>Parupeneus barberinus</i>	Mullidae	1,2,4,5,6,7,8,9,10,11,12,14,15,16,17	II
12	<i>Parupeneus multifasciatus</i>	Mullidae	1,2,3,4,5,6,7,8,9,10,11,12,14,15,16,17	II
13	<i>Cephalopholis cyanostigma</i>	Serranidae	1,2,3,4,5,6,8,9,10,11, 12,13,14,15,16	II
14	<i>Lutjanus fulvus</i>	Lutjanidae	1,3,4,6,8,9,10,11,13, 15,16,17	II
15	<i>Siganus vulpinus</i>	Siganidae	1,5,6,7,8,9,10,11,12, 13,14,15,16	II
16	<i>Acanthurus thompsoni</i>	Acanthuridae	2,3,4,6,11,12,14,15,16	III
17	<i>Lethrinus erythropterus</i>	Lethrinidae	2,3,4,5,8,11,12,15,16, 17	III
18	<i>Caesio teres</i>	Caesionidae	3,6,8,10,11,13,14,15, 17	IV
19	<i>Pterocaesio tile</i>	Caesionidae	15,17	V
20	<i>Lethrinus harak</i>	Lethrinidae	2,3,6,7,8,9,10,11,12, 14,16,17	V

Sampling station: 1 - North Rumberpon; 2 - East Rumberpon; 3 - Purui; 4 - West Purup; 5 - Southeast Purup; 6 - Windesi; 7 - Northwest Yoop; 8 - Northeast Yoop; 9 - South Yoop; 10 - Awori Cape; 11 - Numamuran Gulf; 12 - Manuk Gulf; 13 - Mansinem; 14 - Ayemi Cape; 15 - Matas; 16 - Maransabadi; 17 - Roswar.

Although Table 1 shows that in general each species distributed in several observation stations, but the number of individuals of each species are not evenly distributed at all stations where the species is found. Figure 4 shows the association of fish with the observation station, which can generally be grouped into five groups. Group I was the association between *Caesio cuning* and the observation stations of East part of Purup Island and southern part of Yoop Island. Group II contained the most economic value of fishes which were associated with various observation stations. At these research stations, the presence of fishes were more diverse consisting of *Pterocaesio pisang*, *Ctenochaetus striatus*, *Caesio lunaris*, *Acanthurus pyroferus*, *Pterocaesio digramma*, *Lutjanus biguttatus*, *Monotaxis grandoculis*, *Siganus guttatus*, *Zebrasoma scopas*, *Parupeneus barberinus*, *Parupeneus multifasciatus*, *Cephalopholis cyanostigma*, *Lutjanus fulvus* and *Siganus vulpinus*. The fished distributed widely to several observational stations (North and East parts of Rumberphon Island, Purui Island, West part of Purup Island, Windesi, Northwest part of Yoop Island, Awori Cape, Manuk Gulf, Ayemi Cape, and Maransabadi Island). Group III contained the association between the fish species of *Acanthurus thompsoni* and *Lutjanus erythropterus* and Matas Island. Group IV contained the association between the fish species of *Caesio teres* and Northeast part of Yoop Island, Numamuran Gulf and Mansinem Island. Group V contained the association between fish species of *Pterocaesio tile* and *Lethrinus harak*, and Roswar Island. Spatial distributions of fishes at various observation stations were strongly determined by the dead corals, other fauna, coral and algae mortality index, and abiotic factors.

Changes in the structure of the target fish community is often determined by variations in environmental factors, as fish targets have properties that are integrated with the condition of coral reefs (Choat & Bellwood 1991; Dartnall & Jones 1986; Kuitert 1992). Based on the results of the analysis, it can be seen that the characteristics of the reef is a very influential factor in regulating the distribution and abundance of target fish community. A previous study conducted by Allen (2006) in the same area (Cenderawasih Bay) showed that the highest and lowest diversity were encountered on outer reef slopes and relatively turbid, sheltered reefs respectively. Moderately exposed fringing reefs and offshore patch reefs were intermediate for overall fish species, although the latter habitat was relatively impoverished.

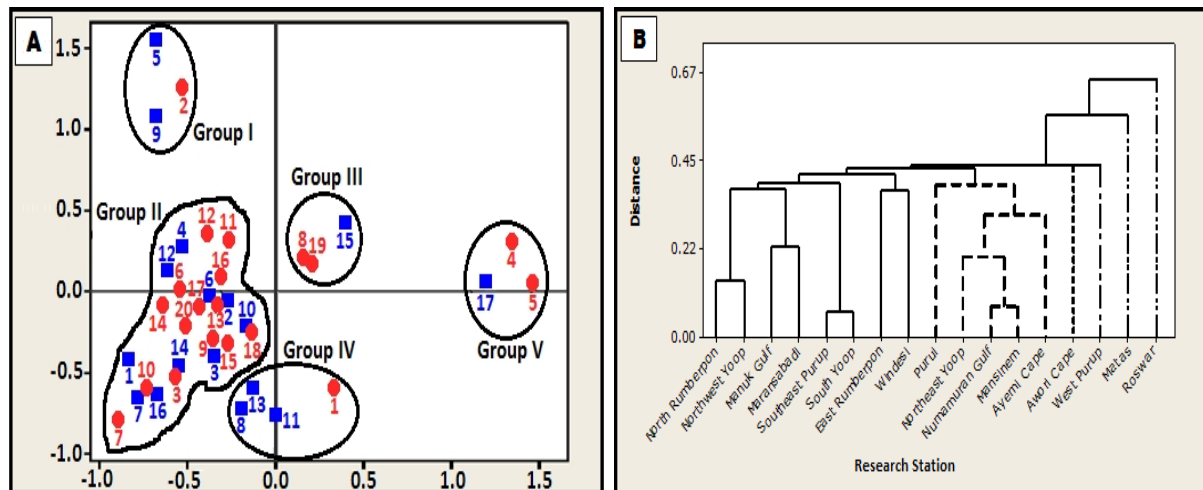


Figure 4. Association of economic target fish based on observation station; Correspondence analysis (A) and Hierarchy analysis (B) (● - fish species; 1 - *Caesio teres*, 2 - *Caesio cunning*, 3 - *Pterocaesio pisang*, 4 - *Pterocaesio tile*, 5 - *Lethrinus harak*, 6 - *Ctenochaetus striatus*, 7 - *Caesio lunaris*, 8 - *Acanthurus thompsoni*, 9 - *Acanthurus pyroferus*, 10 - *Pterocaesio digramma*, 11 - *Lutjanus biguttatus*, 12 - *Monotaxis grandoculis*, 13 - *Siganus guttatus*, 14 - *Zebrasoma scopas*, 15 - *Parupeneus barberinus*, 16 - *Parupeneus multifasciatus*, 17 - *Cephalopholis cyanostigma*, 18 - *Lutjanus fulvus*, 19 - *Lutjanus erythropterus*, 20 - *Siganus vulpinus*; ■ - research station; 1 - North Rumberpon; 2 - East Rumberpon; 3 - Purui; 4 - West Purup; 5 - Southeast Purup; 6 - Windesi; 7 - Northwest Yoop; 8 - Northeast Yoop; 9 - South Yoop; 10 - Awori Cape; 11 - Numamuran Gulf; 12 - Manuk Gulf; 13 - Mansinem; 14 - Ayemi Cape; 15 - Matas; 16 - Maransabadi; 17 - Roswar).

Conclusions. Coral ecosystems in CBNP region are mainly characterized by coral lifeform, dead coral and abiotic factors. Based on habitat characteristic, coral ecosystems in the region are divided into three groups, i.e. the first group characterized by live coral, the second group characterized by dead coral, algae and other fauna, and the third group characterized by abiotic factors. Spatial distribution of fish at various observation stations is strongly determined by the dead corals, other fauna, life coral and algae mortality index, and abiotic factors. Correspondent analysis grouped the association between the research stations and the fish species into several categories based on the research station. The distribution of several fishes i.e. *Caesio lunaris*, *Pterocaesio pisang*, *Pterocaesio digramma*, *Lutjanus biguttatus*, *Monotaxis grandoculis*, *Siganus guttatus*, *Zebrasoma scopas*, *Parupeneus barberinus*, *Parupeneus multifasciatus*, *Cephalopholis cyanostigma*, *Lutjanus fulvus* and *Siganus vulpinus*, might widely spread. These species were found at several research stations.

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