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Analysis of environmental parameters supporting the abundance of *Acanthaster planci* in the Wakatobi and Sombori Marine Protected Areas, Sulawesi, Indonesia

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Abstract. *Jansit AF, Zamani NP, Subhan B, Rachmawati R, Lalang. 2024. Analysis of environmental parameters supporting the abundance of* Acanthaster planci *in the Wakatobi and Sombori Marine Protected Areas, Sulawesi, Indonesia. Biodiversitas 25: 3672-3682.* Wakatobi Islands and Sombori Islands offshore Sulawesi, Indonesia are two marine conservation areas where *Acanthaster planci* (Linnaeus, 1758) is reported. The study was conducted to determine what parameters support the life of *A. planci*, including the composition of coral cover and abundance of reef fish, especially the predatory coral fish of *A. planci*. The relationship between environmental parameters, coral cover conditions, reef fish abundance, and *A. planci* abundance was analyzed using multivariate analysis, namely Principal Component Analysis (PCA). Sampling was conducted using a purposive sampling method based on information on the presence of *A. planci* obtained from local community reports and monitoring reports from related agencies, which was designed to be comprehensive. The determination of observation locations was also based on differences in environmental characteristics, such as nutrient inputs from community settlements. The results showed that *A. planci* was only found in the Sombori Islands as many as 36-117 individuals. The high number in the Sombori Islands was followed by a low cover of live hard corals, a lower abundance of reef fish compared to the observation station in the Wakatobi Islands, and higher pH, salinity, nitrate, and temperature parameters compared to the observation station in the Wakatobi Islands. The high number of *A. planci* individuals was followed by a high percentage of coral break cover and high rock. Coral fractures and nitrate can help increase the likelihood of successful recruitment of *A. planci* larvae, thereby supporting the abundance of *A. planci* in the Sombori Islands.

Keywords: *Acanthaster planci*, coral reef, crown of torn starfish, Sombori, Wakatobi

INTRODUCTION

Coral reef ecosystems are essential for the sustainability of coastal areas and oceans. Coral reef ecosystems play an important role in improving the quality of life of communities, especially coastal communities, such as the availability of food sources and livelihoods, coastal protection, biodiversity, and ecotourism (Ferrario et al. 2014). There is a threat from one of the coral reef association biotas that can be a threat to the coral reef ecosystem namely the Thorny Starfish globally known as the Crown of Thorn Starfish (CoTS), which has the scientific name *Acanthaster planci* (Linnaeus, 1758) which is spread across the Indo-Pacific Region (Yuasa et al. 2021).

The phenomenon of *A. planci* population explosion occurs in several parts of the world, one of which occurs in the Great Barrier Reef of Australia, which caused a decrease in coral cover conditions (Uthicke et al. 2022). The *A. planci* outbreak was reported in Maldives, California, and France Polynesia (Nakamura et al. 2014; Roche et al. 2015; Yasuda 2018). *A. planci* in Indonesia causes coral damage reaching 20 hectares of coral area with a mortality rate of up to 85% (Bairt 2013). In Sulawesi waters, outbreaks of *A. planci* have also been reported as a cause of widespread coral destruction in annual observations in the waters of the Spermonde Islands (Plass-Johnson et al. 2015). The distribution of *A. planci* in Indonesia is extensive, including in Southeast Sulawesi (Arbi et al. 2020) and Central Sulawesi (Malino and Annawati 2020). Clark and Weitzman (2006) explained that *A. planci* is said to be abundant if there are 30-40 individuals per km^2 and can threaten coral reef ecosystems. In the juvenile phase, *A. planci* can consume up to 170 cm^2 of coral tissue annually and will increase to 10 m^2 in the adult phase (Miller et al. 2015; Johansson 2016).

Acanthaster planci has erratic eating preferences when it comes to selecting its food. However, in particular, *A. planci* shows a strong preference for corals from the Acroporidae family, such as the genera Pocillopora and Stylopora, but tends to avoid corals from the Poritidae family (De'ath and Moran 1998). However, other factors influence the feeding preferences of *A. planci,* such as accessibility to prey, availability of prey, and abundance of the most commonly found coral species (Saponari et al. 2018). Other studies have also stated that *A. planci* tend to prey on species that have been recognized or previously consumed (Johansson 2016). Several studies explain the factors that lead to the increase in abundance and distribution of *A. planci*, such as a reduction in predators in the larval and adult individual phases (Li et al. 2019), the availability of food to increase larval recruitment and ocean currents (Zhang et al. 2022).

Given the impact that can be caused, the existence of *A. planci* in an area needs to be watched. Sahri (2012) and Asmara et al. (2013) reported a high abundance of *A. planci* in the Wakatobi Islands, Southeast Sulawesi waters. In addition, Jansit et al. (2024) also reported a high abundance in the waters of the Sombori Islands, Central Sulawesi. These two waters are designated as marine national parks through Wakatobi National Park (Decree of the Minister of Agriculture Number 7661/Kpts-II/2002) and Coastal and Small Islands Conservation Areas (Decree of KepMenKP Number. 52/KEPMEN-KP/2019). The main factors that can cause fluctuations in the abundance of *A. planci* in these waters are unknown. However, globally, several hypotheses have been proposed to identify the main factors that cause the outbreak, including natural and anthropogenic sources such as food availability, ocean currents, adult aggregation, nutrient enrichment, and capture of *A. planci* predators. This can increase the survival rate of larvae and juveniles (Babcock et al. 2016; Pratchett et al. 2017). Therefore, a study on the relationship between *A. planci* abundance and environmental conditions needs to be carried out to analyze the factors that cause the presence of *A. planci* in an area, especially in these two areas.

MATERIALS AND METHODS

Study area

Data collection was carried out offshore Sulawesi, Indonesia in October 2023 on Wanci Island, Kapota Island, and Kamponaone Island of Wakatobi Islands, Southeast Sulawesi, and in November 2023 on Dongkalan Kecil Island and Mbokitta Island of Sombori Islands, Central Sulawesi (Figure 1). The Wakatobi observation station is coded as StW, whereas the Sombori observation station is coded as StS.

Procedure

Coral cover sampling

Data collection of coral reef conditions using the Underwater Photo Transect (UPT) method. Next, a 50 m transect in Wakatobi and a 100 m transect in Sombori were placed parallel to the shoreline at each observation station. After the transect line is installed, photographing is done using an underwater camera. Shooting starts from the 1st meter on the left and the 2nd meter on the right. Shooting continued until the end of the transect. Shooting with odd numbers (1,3,5...) was taken on the left side, while even numbers (2,4,6...) were taken on the right side of the transect line. The results of the shooting were then analyzed using Coral Point Count with Excel (CPCE) software, which produced data efficiently and practically (Kholer and Gill 2006). The percentage of substrate cover is categorized based on groups of live corals, dead corals, other, and abiotic. The category of live corals is identified based on the lifeform of corals consisting of Acropora and Non-Acropora corals.

The density of coral fish sampling

Coral fish data were collected using the Underwater Visual Census (UVC) method, which records each type of fish that enters the transect. The transects' length and width followed the transects' length in the data collection of *A. planci*. Each type of fish is identified and grouped into major fish, target fish, and indicator fish. To calculate the density of coral fish (Xi), we use the equation by Odum (1993), i.e., the number of fish to-i (ni) divided by the total area of the observation area:

$$Xi = \sum \frac{ni}{L}$$

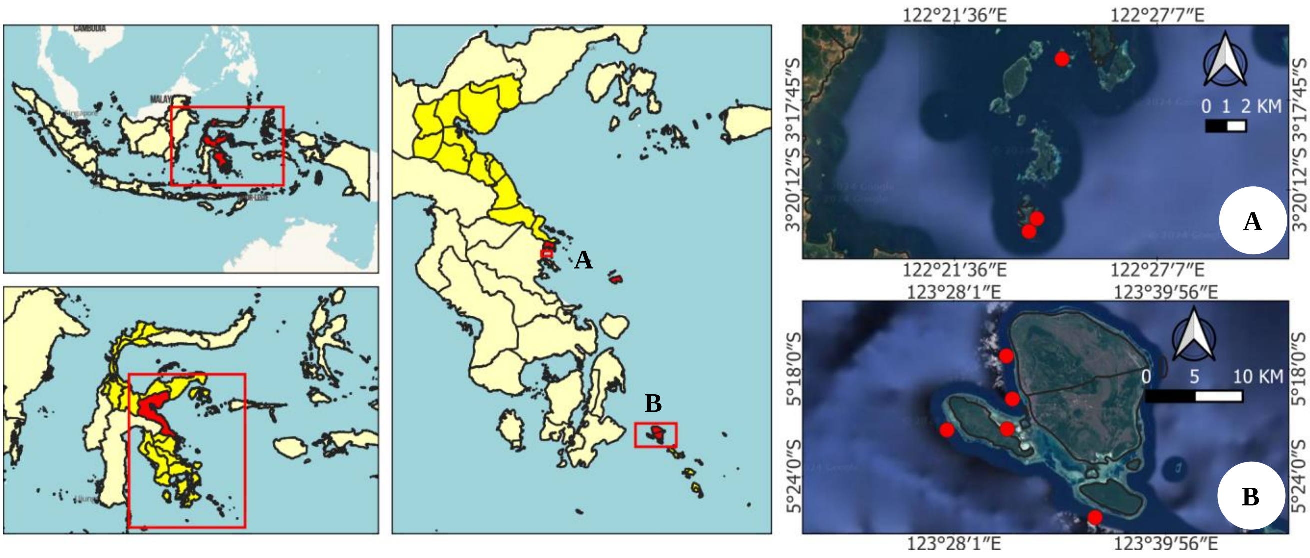

Figure 1. Study sites in A. Sombori Islands, Morowali, Central Sulawesi; B. Wakatobi Islands, Wakatobi, Southeast Sulawesi, Indonesia

Density of Acanthaster planci *sampling*

The collection of *A. planci* abundance data uses the belt transect method with a transect length of 50 m in the Wakatobi Islands, while in the Sombori Islands, a transect is used 100 m long transect; considering sampling time, workforce, and cost efficiency but still producing representative data with an observation width of 2.5 m to the right and 2.5 m to the left. The diversity of *A. planci* was calculated based on the accompanying by Bikerland and Lucas (1990), i.e., the number of individuals united by the area of observation.

$$N = \frac{\sum n}{A}$$

Environmental parameters sampling

Environmental quality data is collected in situ by measuring directly in the field and sampling seawater. The parameters measured were physical parameters, namely temperature, brightness, and chemical parameters in the form of pH, salinity, and nutrients (nitrates and phosphates). The parameters that are directly measured are temperature, brightness, pH, and salinity. Meanwhile, the concentration of nutrients (nitrates and phosphates) was analyzed by taking seawater samples put into sample bottles and then analyzed at the Biomolecular and Environmental Laboratory, FMIPA, Universitas Halu Oleo.

Data analysis

The relationship between the abundance of *A. planci* with nutrient concentrations and coral reef conditions was analyzed using Principal Component Analysis (PCA). This analysis is a statistical overview to display data in graphs and information in a data matrix. PCA analysis was carried out with the help of the Microsoft XL-STAT computer program version 2023.3.1. PCA analysis was carried out with the help of the Microsoft XL-STAT computer program with the following equation.

$$d^2(i, i`) = \sum_{J=1}^{p} (X_{ij} - X_{ij})$$

Where: *i* are two rows and *j* is the column index (varies from 1 to *p*). The smaller the Euclidean distance between substations, the more similar the environmental characteristics between those stations.

RESULTS AND DISCUSSION

Coral cover

The percentage of substrate cover is categorized based on English et al. (1994), which is divided into major categories such as Hard Coral (HC) or live coral, Dead Coral (DC), Other fauna (OT), Algae (ALGAE) and Abiotic (ABIOTIC). The condition of coral reefs in the Wakatobi Islands and Sombori Islands (Figure 2) shows that the percentage of live coral cover in the Wakatobi Islands ranges from 29.84-51.91 (middle-good), while in the Sombori Islands it ranges from 10.89-34.44 (poor-middle). The difference in coral cover conditions between Wakatobi and Sombori is due to different levels of surveillance. One of the biggest causes of damage to coral reefs in the Sombori Islands is destructive fishing using bombs, which still often occurs due to lack of supervision. At the same time, the supervision of coral reefs in the Wakatobi Islands has been well managed and supervised by the Wakatobi National Park Center.

The highest percentage of HC cover in the Wakatobi Islands was in StW I at 51.91. The high percentage of HC in the Wakatobi Islands is because the waters have a high level of brightness that supports coral life. Water brightness is related to suspended solids, which are particles suspended in the water, and light entering the water column. These suspended solids can provide nutrients for the coral symbiont organisms (zooxanthellae) to photosynthesize to produce food for coral animals (Thamrin 2017). The lowest station in the Wakatobi Islands is at StW IV of 29.84, located on the west side of Kapota Island. This can be caused by several factors such as geographical location that does not allow coral reefs to survive due to wave exposure in certain seasons and fishing activities. At station IV, remnants of fishing gear nets are trapped on the reef. In addition, several spots of dead coral were also found. During the data collection, fishermen were also seen using motorized boats on coral reefs in fairly shallow waters. This is a risk of collision between the boat and the coral reef. Boat activities and fishing boat berths damage the coral reef ecosystem which causes low diversity of associated biota. In addition, the low percentage of HC in St IV is also followed by a high percentage of DC of 44.53, consisting of dead coral, dead coral overgrown with algae, and broken coral. This suggests that coral mortality occurred in the past. In addition (Yulius et al. 2015) reported high DC cover in the Wakatobi Islands caused by non-environmentally friendly fishing activities using bombs that have occurred since 2000. The percentage of other components, namely OT in Wakatobi waters ranges from 1.78 to 18.73, the highest percentage is found in StW III which is due to the fact that in StW III there are more sponges compared to other StWs. Sponges have a faster growth rate than corals so they can dominate covering corals in a location. In addition to sponges, other fauna found are soft corals, anemones and gorgonians. The next component is abiotic with a percentage ranging from 8.09 to 38.40 consisting of sand and rock.

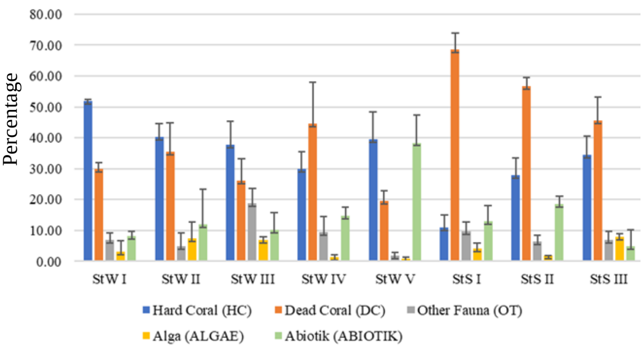

Figure 2. Coral reef cover percentage in Wakatobi (StW) and Sombori (StS) Islands, Sulawesi, Indonesia

The highest percentage of HC cover in the Sombori Islands is in StS III of 34.44, located on Mbokitta Island. The lowest is in StS I of 10.89, located on the south side of Dongkalan Kecil Island. The DC component in StS I Sombori is 62.28. The percentage of DC cover in the Sombori Islands consists of dead coral components, dead corals overgrown with algae, and broken corals. The high DC group in the Sombori Islands is caused by environmentally unfriendly fishing activities that occurred in the past until now. In addition, the high percentage of dead coral cover overgrown with algae indicates that there has been coral mortality in the past, but the exact cause of death is unknown due to poor monitoring of coral reef conditions in the Sombori Islands Jouffray et al. 2015) reported a dominance by macroalgae and turf algae after coral bleaching events. The OT component in Sombori waters ranged from 6.35-9.67, consisting of sponges, etc. Abiotic components in the Sombori Islands ranged from 5-18.52, with the highest percentage found in StS I consisting of sand and rock. The Sombori Islands consist of karst islands, so the percentage of sand and rock is quite high. The highest algae component is found in StS III, which consists of macroalgae. This can be caused because in StS III there are settlements that are on the surface of the water, so that nutrients tend to be higher than others. Based on the results of nitrate and phosphate analysis also show that the carrier in StS III has a high percentage of nutrients. Nutrients can help the growth of macroalgae as well as microalgae.

Coral growth forms at all Wakatobi and Sombori (Table 1) stations are dominated by corals with massive lifeforms with percentages between 18.49-22.11 in the Wakatobi Islands and 5.61-19.92 in the Sombori Islands. Panggabean et al. (2017) mentioned that corals with massive and submassive growth forms have a high level of resilience and are resistant to specific aquatic conditions, such as high sedimentation and low light, even in murky waters. Massive coral has a shape resembling a solid and rounded rock, while the submassive growth form tends to form columns, knobs, or small slices (English et al. 1994). So, massive corals can dominate in one location. Fahlevy et al. (2024) state that corals from the Acroporidae and Poritidae families are the most dominant corals in the waters of the Wakatobi National Park. The most massive coral species found in Wakatobi and Sombori stations are coral species from the Poritidae family. Corals from the Poritidae family have a growth trend that tends to decrease in increasing temperature conditions (Zamani et al. 2017).

The coral fish density

Fish can be used as bioindicators to determine the condition of coral reefs and the threat of environmental changes such as pollution in marine ecosystems. Observations of reef fish based on family groups and the number of individuals were grouped into three major groups: target fish, indicator fish, and major fish. The results of observations of reef fish in the Wakatobi Islands (Table 2) show an abundance of 0.51-0.86 with a total number of 2,555 individuals.

The lowest density (Figure 3) of reef fish in the Wakatobi Islands is found in StW II. This is related to the condition of coral reefs, which are the habitat of reef fish. The lower the condition of coral reefs, the composition of reef fish will also decrease. Reef fish groups make coral reef ecosystems as habitat, so if the condition of coral is damaged it will affect the abundance of reef fish. This is in line with the research of Lisna et al. (2022), that generally, the abundance of reef fish is positively correlated with the percentage of live coral cover.

The density of reef fish in the Sombori Islands is between 0.31-0.63. The lowest abundance of reef fish is found at StS I. The low density of reef fish at this point is related to the condition of coral cover, which is also low. Reef fish are associated with coral reef ecosystems ecologically, so if the condition of coral cover is low, the abundance of reef fish is also low; the most numerous fish groups in the Sombori Islands are fish from the target and major groups.

Table 1. Percentage of live coral cover by lifeform in Wakatobi and Sombori Islands, Sulawesi, Indonesia

Lifeform (%)	StW I	StW II	StW III	StW IV	StW V	StS I	StS II	StS III
Acropora Branching (ACB)	4.18	1.87	0.29	0.04	1.73	0.78	2.85	0.06
Acropora Digitate (ACD)	0.13	1.02	0.62	0.51	0.51	0.06	0.06	-
Acropora Encrusting (ACE)	0.44	1.33	0.84	0.07	-	-	-	-
Acropora Submassive (ACS)	7.97	0.76 ±	2.6	-	3.87	-	0.62	4.89
Acropora Tabular (ACT)	1.67	0.22	4.36	-	0.78	0.33	0.39	0.06
Coral Branching (CB)	1.47	1.82	2.53	0.58	7.49	0.5	0.51	0.78
Coral Encrusting (CE)	3.56	1.09	3.27	2.33	1.22	1.67	1.78	9.33
Coral Foliose (CF)	3.51	1.69	0.02	0.18	0.62	1.11	0.62	2.39
Coral Heliopora (CHL)	3.73	1.98	0.51	6.80 9	0.22	-	-	0.22
Coral Juvenile (CORJU)	-	-	-	-	-	0.67	0.68	0.06
Coral Massive (CM)	18.64	22.07	22.11	18.49	15.89	5.61	19.24	12.44
Coral Millepora (CME)	0.07	3.33	0.02	0.02	1.6	-	-	-
Coral Mushroom (CMR)	2.69	0.40	0.18	-	0.36	0.11	0.51	2.33
Coral Submassive (CS)	3.76	2.76	0.51	0.82	5.16	0.06	0.75	1.89
Coral Tubipora (CTU)	-	0.04	-	-	-	-	-	-
Totals	51.91	40.38	37.87	29.84	39.44	10.89	28.01	34.44
Category	Good	Middle	Middle	Middle	Middle	Poor	Middle	Middle

The results of the index analysis (Table 3) H' in the Wakatobi Islands show that StW I, II, III, and IV have a high diversity status while StW V's diversity status is in the medium category. The Sombori Islands show that StS I and II are in the medium diversity category, but StS III is in the high diversity category. The E index in the Wakatobi Islands shows that the level of fish uniformity in all Sts of the Wakatobi Islands is in the high uniformity category. In the Sombori Islands, the level of reef fish uniformity is also high. The C index in the Wakatobi Islands ranges from 0.05-0.11, meaning that in StW I and IV, there are no dominating species, while in StW II, III, and V, there are dominating species. In the Sombori Islands, the C index shows that in StS III, there are no dominating species, while in StS I and II, there are dominating species.

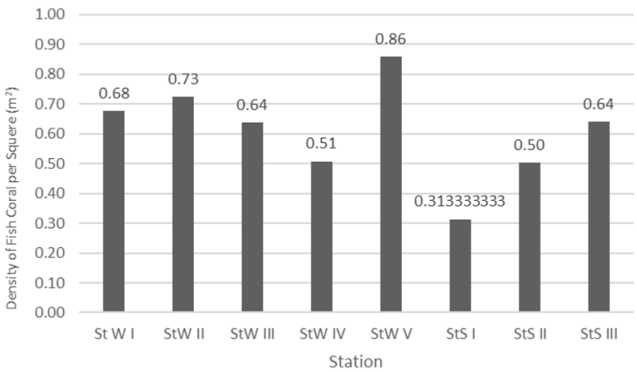

Figure 3. Density of coral fish in Wakatobi and Sombori Islands, Sulawesi, Indonesia

Table 2. Coral fish abundance (individuals/m²) in Wakatobi and Sombori Islands, Sulawesi, Indonesia

Category	Family	Species	StW I	StW II	StW III	StW IV	StW V	StS I	StSII	StS III
Target fish	Acanthuridae	*Acanthurus pyroferus*	4	4	0	14	0	0	0	0
	Acanthuridae	*Acanthurus thompsoni*	11	18	5	0	0	0	0	0
	Acanthuridae	*Acanthurus blochii*	0	0	7	0	0	0	3	0
	Acanthuridae	*Zebrasoma scopas*	30	27	0	0	0	0	0	0
	Acanthuridae	*Naso lituratus*	5	5	0	0	0	0	0	0
	Acanthuridae	*Acanthurus lineatus*	0	0	0	0	0	3	8	13
	Acanthuridae	*Acanthurus nubilus*	0	0	0	0	0	5	11	11
	Acanthuridae	*Acanthurus olivaceus*	0	0	0	0	0	3	0	7
	Acanthuridae	*Aulostomus chinensis*	2	2	0	0	0	0	0	0
	Acanthuridae	*Naso lopezi*	0	0	63	0	0	0	0	0
	Acanthuridae	*Naso annulatus*	0	0	14	0	0	0	0	0
	Acanthuridae	*Ctenochaetus striatus*	0	0	0	1	25	7	5	11
	Acanthuridae	*Ctenochaetus binotatus*	0	0	20	9	4	0	0	0
	Caesionidae	*Caesio teres*	15	0	0	0	0	8	8	8
	Caesionidae	*Caesio cuning*	0	0	0	0	0	3	0	9
	Caesionidae	*Caesio lunaris*	0	0	0	0	0	5	5	0
	Caesionidae	*Pterocaesio trilineata*	8	0	0	0	0	0	0	0
	Caesionidae	*Pterocaesio marri*	2	0	0	0	0	0	0	0
	Lutjanidae	*Lutjanus biguttatus*	63	71	0	34	11	0	0	0
	Lutjanidae	*Lutjanus fulvus*	3	3	0	0	0	0	0	0
	Lutjanidae	*Lutjanus gibbus*	0	5	0	0	0	0	0	0
	Scaridae	*Scarus flavipectoralis*	45	33	0	0	0	0	0	0
	Scaridae	*Scarus scaber*	8	1	0	0	0	0	0	0
	Scaridae	*Scarus dimidiatus*	0	0	35	0	7	0	0	0
	Scaridae	*Scarus forsteni*	0	0	4	0	0	0	0	0
	Scaridae	*Chlorurus sordidus*	0	0	0	8	4	0	0	0
	Scaridae	*Chlorurus frontalis*	0	0	0	0	0	6	0	8
	Scaridae	*Scarus niger*	0	0	0	0	0	11	9	7
	Serranidae	*Cephalopholis leopardus*	2	4	7	3	0	0	0	0
	Serranidae	*Epinephelus quoyanus*	7	5	0	3	3	0	0	0
	Labridae	*Anampses melanurus*	2	2	0	24	0	0	0	0
	Labridae	*Cheilinus fasciatus*	1	1	0	14	0	0	0	0
	Labridae	*Cheilinus chlorourus*	0	0	8	0	2	0	0	0
	Labridae	*Choerodon anchorago*	1	4	0	0	4	0	0	0
	Labridae	*Cirrhilabrus aurantidorsalis*	4	0	0	0	0	0	0	0
	Labridae	*Gomphosus varius*	2	2	0	0	0	0	0	0
	Labridae	*Halichoeres leucoxanthus*	20	11	3	15	24	0	0	0
	Labridae	*Halichoeres hortulanus*	0	0	0	2	0	0	0	0
	Labridae	*Labroides dimidiatus*	5	7	0	28	1	0	0	0
	Labridae	*Thalassoma lunare*	1	4	8	5	0	0	0	0
	Labridae	*Thalassoma hardwicke*	0	0	12	31	0	0	0	0
	Labridae	*Cirrhilabrus solorensis*	0	0	19	0	0	0	0	0
	Labridae	*Cheilio inermis*	0	0	5	13	3	0	0	0

	Holocentridae	*Neoniphon aurolineatus*	5	7	0	0	0	0	0	0
	Holocentridae	*Sargocentron cornutum*	4	4	0	0	0	0	0	0
	Siganidae	*Siganus tetrazonus*	0	0	6	0	0	0	0	0
	Siganidae	*Forcipiger longirostris*	0	0	0	2	0	0	0	0
	Nemipteridae	*Scolopsis trilineata*	4	9	0	0	22	0	0	0
	Nemipteridae	*Scolopsis bilineata*	0	0	9	0	31	0	0	0
	Nemipteridae	*Scolopsis xenochrous*	0	0	0	34	0	0	0	0
Indicator fish	Chaetodontidae	*Chaetodon trifasciatus*	14	17	23	6	8	4	3	0
	Chaetodontidae	*Chaetodon punctatofasciatus*	0	0	0	19	0	0	0	0
	Chaetodontidae	*Chaetodon kleinii*	0	0	0	0	0	4	0	0
	Chaetodontidae	*Chaetodon lunulatus*	0	0	0	0	0	0	4	2
	Chaetodontidae	*Chaetodon melannotus*	0	0	0	0	0	3	7	9
	Chaetodontidae	*Chaetodon auriga*	0	0	0	0	0	4	8	4
	Chaetodontidae	*Heniochus acuminatus*	19	22	23	0	14	0	0	0
	Chaetodontidae	*Heniochus pleurotaenia*	6	8	0	0	0	0	0	0
	Chaetodontidae	*Forcipiger flavissimus*	0	0	0	0	0	2	5	3
	Chaetodontidae	*Hemitaurichthys polylepis*	0	0	0	0	0	0	2	9
	Chaetodontidae	*Parachaetodon ocellatus*	0	0	15	0	0	0	0	0
Major fish	Apogonidae	*Ostorhinchus cyanosoma*	0	0	0	0	71	0	0	0
	Apogonidae	*Archamia macroptera*	0	0	0	0	34	0	0	0
	Apogonidae	*Ostorhinchus compressus*	0	0	0	0	0	6	9	12
	Apogonidae	*Apogon kiensis*	0	0	0	0	0	2	13	11
	Pomacentridae	*Amphiprion frenatus*	23	19	0	0	0	0	0	0
	Pomacentridae	*Amphiprion ocellaris*	5	0	0	0	0	0	0	0
	Pomacentridae	*Chromis caudalis*	8	8	0	12	41	0	0	0
	Pomacentridae	*Chromis viridis*	18	118	0	11	25	0	0	0
	Pomacentridae	*Chromis atripes*	0	0	34	9	134	0	0	0
	Pomacentridae	*Chrysiptera bleekeri*	0	0	13	0	115	0	0	0
	Pomacentridae	*Chrysiptera hemicyanea*	0	0	6	29	0	0	0	0
	Pomacentridae	*Chrysiptera talboti*	0	0	9	5	5	0	0	0
	Pomacentridae	*Dascyllus trimaculatus*	47	21	0	0	0	0	0	0
	Pomacentridae	*Dascyllus reticulatus*	14	9	0	10	0	0	0	0
	Pomacentridae	*Pomacentrus moluccensis*	32	14	34	0	8	0	0	0
	Pomacentridae	*Abudefduf bengalensis*	0	0	0	0	11	0	0	0
	Pomacentridae	*Abudefduf vaigiensis*	0	0	0	0	31	0	0	0
	Zanclidae	*Zanclus cornutus*	8	2	12	5	0	0	0	0
	Balistidae	*Balistes verrucosus*	0	0	0	0	0	2	0	10
	Balistidae	*Balistapus undulatus*	7	7	10	1	0	3	12	10
	Balistidae	*Odonus niger*	8	19	0	9	0	0	0	0
	Mullidae	*Parupeneus bifasciatus*	7	9	9	0	0	0	0	0
	Mullidae	*Parupeneus macronemus*	5	6	19	0	0	0	0	0
	Cirrhitidae	*Paracirrhites forsteri*	1	1	2	15	4	0	0	0
	Pomacanthidae	*Centropyge flavicauda*	8	8	0	0	0	0	0	0
	Pomacanthidae	*Centropyge vrolikii*	9	9	0	5	0	0	0	0
	Pomacanthidae	*Centropyge bicolor*	0	0	1	0	0	0	0	0
	Pomacanthidae	*Chaetodontoplus mesoleucus*	0	0	5	0	0	0	0	0
	Pomacanthidae	*Pygoplites diacanthus*	0	0	2	0	0	0	0	0
	Pomacanthidae	*Amphiprion ocellaris*	0	0	0	0	0	0	10	13
	Pomacanthidae	*Amphiprion clarkii*	0	0	0	0	0	0	15	13
	Pomacanthidae	*Chromis caudalis*	0	0	0	0	0	5	12	0
	Pomacanthidae	*Pomacentrus armillatus*	0	0	0	0	0	8	2	22
	Synodontidae	*Synodus saurus*	3	0	4	5	3	0	0	0
	Centriscidae	*Centriscus scutatus*	11	18	0	0	0	0	0	0
	Tiodontidae	*Diodon liturosus*	0	0	3	0	0	0	0	0
	Grammistidae	*Diploprion bifasciatum*	0	0	22	0	0	0	0	0
	Ostraciidae	*Ostracion rhinorhynchos*	0	0	1	0	0	0	0	0
	Scorpaenodae	*Pterois volitans*	0	0	2	0	0	0	0	0
	Tetraodontidae	*Canthigaster valentini*	0	0	4	0	0	0	0	0
	Target fish		254	229	225	240	141	51	49	74
	Indicator fish		39	47	61	25	22	17	29	27
	Major fish		214	268	192	116	482	26	73	91
	Total individu		507	544	459	381	645	94	151	189

Table 3. Diversity, uniformity, dominance index of coral fish

Index	St W I	St W II	St W III	St W IV	St W V	St S I	St S II	St S III
H'	3.31	3.31	3.14	3.13	2.59	2.88	2.86	3.02
E	0.87	0.90	0.89	0.91	0.79	0.96	0.96	0.98
C	0.05	0.08	0.06	0.05	0.11	0.06	0.06	0.05

Table 4. The abundance of predatory fish species of *Acanthaster planci* from juvenile to adult levels

Species fish	StW I	StW II	StW III	StW IV	StW V	StS I	StS II	StS III
Chaetodon auriga	0	0	0	0	0	4	8	4
Chromis atripectoralis	0	0	34	9	134	0	0	0
Chromis viridis	18	118	0	11	25	0	0	0
Dascyllus reticulatus	14	9	0	10	0	0	0	0
Pomacentrus moluccensis	32	14	14	0	8	0	0	0
Thalassoma hardwicke	0	0	12	31	0	0	0	0
Thalassoma lunare	1	4	8	5	0	0	0	0

Source: Cowan et al. 2017

The lack of predators that prey on *A. planci* also contributes to the abundance of *A. planci* in an area. Several marine biotas have been observed to prey on juvenile to adult *A. planci*, such as Crustacea, fish, and shellfish species. Several fish species have been identified to prey on *A. planci* from juvenile to adult levels. The number of fish predators of *A. planci* found in Wakatobi waters (Table 4) is quite large, with 6 types of fish found. Meanwhile, in Sombori waters there is only 1 type of *A. planci* predatory fish found.

The abundance of *Acanthaster planci*

Our observations on the Wakatobi Islands did not show the presence of *A. planci*. However, at StW V, located at the entrance to Kapota, we found white skeletal remains in the coral tabulate, believed to be the remains of *A. planci* predation. Sahri's report (2012) was instrumental in our understanding of the high abundance of *A. planci* at the Kapota entrance observation point. At the Sombori Islands observation location, *A. planci* was found in high abundance, accompanied by low live coral cover and a high percentage of dead coral.

Observation density of *A. planci* was only found in Sombori. The density value (Figure 4) was 0.13 in StS I, then 0.39 in StS II, and 0.08 in StS III. Observations in the Sombori Islands found *A. planci* with a large number, namely at StS I at 39 individuals, StS II at 117 individuals, and StS III at 25 individuals. The highest density is located in StS II, which is located on the east side of Dongkalan Kecil Island. Jansit et al. (2022) reported a high presence of *A. planci* on Dongkalan Kecil Island, reaching 123 individuals. The occurrence of *A. planci* in the Sombori Islands was followed by higher temperature and salinity parameters and a lower percentage of HC cover than in the Wakatobi Islands. Temperature can be one of the factors that affect the presence of *A. planci* in the Sombori Islands; this is also explained by Johnson and Babcock (1994), which states that the spiny starfish outbreak in the Australian GBR began in the northern part of the GBR, which has warmer waters compared to the south which has cooler water temperatures. In addition (Li et al. 2019) found that the breeding season of *A. planci* stars on Xisha Island occurs in summer, and higher temperatures can increase the survival rate of *A. planci* larvae.

The presence of *A. planci* in coral reef observation sites has a negative impact because it can damage and eat coral polyps. *A. planci* is a plague for coral reef ecosystems (Baird et al. 2013). The condition of coral cover can affect the abundance of *A. planci* in a location, such as the shape of the substrate, and the composition of the constituents of the coral reef ecosystem, such as the composition of algae and coral breaks (Ningsih et al. 2021). In addition, nutrient enrichment can also cause a high abundance of *A. planci*. Understanding and addressing these factors is crucial for the conservation of coral reef ecosystems, and our role as a conservationist or researchers is pivotal in this endeavor.

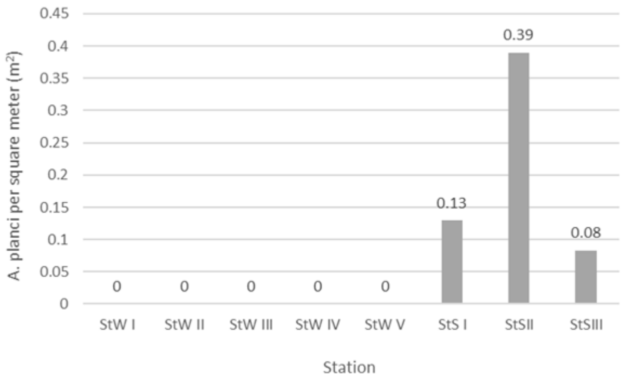

Figure 4. The abundance of *Acanthaster planci* on Sombori Islands, Central Sulawesi, Indonesia

Acanthaster planci has erratic feeding preferences in terms of selecting its diet. However, in particular, *A. planci* shows a strong preference for corals from the Acroporidae family, such as the genera Pocillopora and Stylopora, but tends to avoid corals from the Poritidae family (De'ath and Moran 1998). However, other factors influence the feeding preferences of *A. planci*, such as accessibility to prey, prey availability, and abundance of the most common coral species (Saponari 2018). Other studies also mention that *A. planci* tends to prey on species that have been recognized or previously consumed (Johansson 2016). Observations showed (Figure 5) that *A. planci* was found on the surface of corals, especially corals from massive, branching, and tabulated growth forms.

Physicochemical characteristic

The environmental parameter conditions (Table 5) in the waters of the Wakatobi Islands and Sombori Islands show different values of temperature, salinity, nitrate, and phosphate. The temperature in the Wakatobi Islands ranges from 26.9 to 28.7, while the waters of the Sombori Islands range from 28.4 to 28.7. The salinity value in the Wakatobi Islands ranges from 33.5 to 33.8, while in the waters of the Sombori Islands, it is 34 at all points of the station; both observation locations have salinity conditions that support coral life. The nitrate level in the Wakatobi Islands ranges from 0.006 to 0.021, while in the waters of the Sombori Islands range from 0.006 to 0.008. Phosphate concentrations in the Wakatobi Islands ranged from 0.004 to 0.012, while in the Sombori Islands ranged from 0.010 to 0.014.

The temperature parameter in StW III is the lowest temperature, which is 26.9. Chandra et al. (2016) show that this region has an average temperature between 28.90 to 28.97. So that the low temperature at St III Wakatobi can be caused by the measurement time carried out in the morning so that the sea water temperature tends to be lower. The temperature in the Sombori Islands is relatively the same at each station because the data collection time is carried out during the day. Hence, the flow temperature is relatively the same. Sunlight is a factor that affects the temperature of seawater.

The salinity value in the Wakatobi Islands tends to be lower than in the Sombori Islands. This can be attributed to the difference in the islands' locations, which affect the condition of the waters. The Wakatobi Islands are located in open waters in the Banda Sea. In comparison, the Sombori Islands are located at the mouth of Lasolo Bay and are close to large islands with spring water sources, which also affect the salinity value.

Figure 5. *Acanthaster planci* found on Sombori Islands, Central Sulawesi, Indonesia

Table 5. Physicochemical characteristics in Wakatobi and Sombori Islands, Sulawesi, Indonesia

Environmental parameters	**Unit**	**StW I**	**StW II**	**StW III**	**StW IV**	**StW V**	**StS I**	**StS II**	**StS III**
Temperature	°C	27.6	28.2	26.9	27.1	28.7	28.4	28.4	28.7
Salinity	ppt	33.5	33.7	33.6	33.6	33.8	34	34	34
Turbidity	%	100	100	100	100	100	100	100	100
pH	-	7.2	7.2	7.2	7.3	7.3	7.3	7.3	7.3
Nitrate	mg/L	0.014	0.021	0.006	0.014	0.018	0.008	0.006	0.006
Phosfate	mg/L	0.008	0.004	0.012	0.008	0.012	0.014	0.012	0.010

The highest nitrate levels in the Wakatobi Islands are located at St II because it is located in Wambuliga Village, an upwelling area, so the waterbed's nitrate level affects the water column's nitrate level. The lowest nitrate level in the Wakatobi Islands is in StW III. In the Sombori Islands, the highest nitrate levels are found in StS I because it is located on the south side of Dongalan Kecil Island. Hence, the turbulence of waves and currents causes higher nutrients at this station. The highest phosphate levels in the Wakatobi Islands are found in StW III and V; this is due to the sampling location being carried out in a sloping area so that the phosphate concentration is higher than other St. Meanwhile, in the Sombori Islands, it is found in StS I because water sampling is carried out in an area close to the mainland so that the concentration of phosphate is higher in this station.

Principal Component Analysis (PCA)

The results of interpreting the contribution of the two main components of factors 1 and 2 (Figure 6) to the total variety reached 73.96%. The plot graph of the relationship of each environmental parameter (Figure 6.A) shows that the parameters of salinity, pH, and abundance *of A. planci* are positively correlated or mutually influencing each other. The influence can be seen from the vector lines forming small angles and pointing in the same direction. Other parameters that have a positive effect are the HC and nitrate parameters that can be seen on the vector line that forms a slight angle to the main component of the factor. Thus, the environmental parameters that contribute the most to the overall total variety are the parameters of HC, nitrate, salinity, and pH. The research of Wolfe et al. (2015) showed that nutrient inputs in the aquatic environment contribute to the metamorphosis process of *A. planci* larvae in accelerating the settlement process from the pelagic phase to the benthic phase of *A. planci*.

The distribution of zones based on environmental parameters (Figure 6.B) shows that StW V Wakatobi and StS I, II, and III are on the positive axis of the total main components of factors 1 and 2. This means that the four stations have environmental characteristics characterized by temperature, nitrate, salinity, and pH parameters that tend to be the same. Temperature is a parameter that supports the activity of *A. planci* which tends to move to forage in warmer waters actively. Li et al. (2019) reported that the recorded intensity of *A. planci* outbreaks was more common in areas with higher temperatures. Aquatic environmental parameters in the Sombori Islands, such as temperature and nitrate, are higher than in the Wakatobi Islands, where *A. planci* is not found. Nitrate is a derivative of the bond of Nitrogen (N), which can increase chl-a production. Wolve et al. (2015) explains that the survival rate of *A. planci* larvae is higher at higher chl-a levels, and there is a more significant increase in length than in water conditions with lower chl-a levels.

The PCA analysis between the abundance of *A. planci* and the composition of coral cover in the Sombori Islands (Figure 7.A) shows that the vector lines of abundance of *A. planci*, HC, RCK, and R form a slight angle to the main components. This suggests that the abundance of *A. planci* in HC, RCK, and R compositions is related; the R components or coral faults can be a habitat for juvenile *A. planci* to increase its survival of *A. planci*. Coral faults can also protect them from predators in the juvenile phase (Mallino and Annawaty 2020; Ningsih et al. 2021). In addition, the RCK or Rock component can also make it easier for the movement pattern of *A. planci* to move to a point. The distribution of stations is based on the characteristics of coral cover composition (Figure 7.B), which shows that the vector points of StS II and III are on the positive axis while StS I is on the negative axis. This means that StS II and III have cover characteristics that are the same compared to StS I. Based on the coral cover percentage results, the components HC, RCK, and R have the same percentage between StS II and III compared to StS I. Generally, the abundance of *A. planci* is negatively correlated with the percentage of coral cover, which means the percentage of coral cover will decrease if there is an abundance of *A. planci*. Zamani et al. (2017) also found that observations of locations that had a higher number of *A. planci* were followed by a lower percentage of coral cover.

The interpretation of the results of the matrix correlation between the abundance *of A. planci* and the composition of coral cover in the Sombori Islands shows that the abundance *of A. planci* is positively correlated with the components HC, DC, R, RCK, and S. This shows that the higher the ratio of HC, DC, R, RCK, and S, the higher the abundance of *A. planci* is also high in the Sombori Islands. Mallino and Annawaty (2020) and Ningsih et al. (2022) mentioned that substrates also affect the presence of *A. planci* as substrates consisting of coral faults can grow thread algae and vine algae utilized as food by *A. planci* in the larval phase, and coral faults or R can also protect them from predators in the juvenile phase. *Acanthaster planci* will move towards the location where there are coral reefs that become their food and will then cause coral death at that location so that these two components are positively correlated with *A. planci* abundance. Meanwhile, the correlation with the RCK and S components can simplify the movement pattern *of A. planci* so that the higher the RCK and S, the easier it is for *A. planci* to move and move from one coral to another.

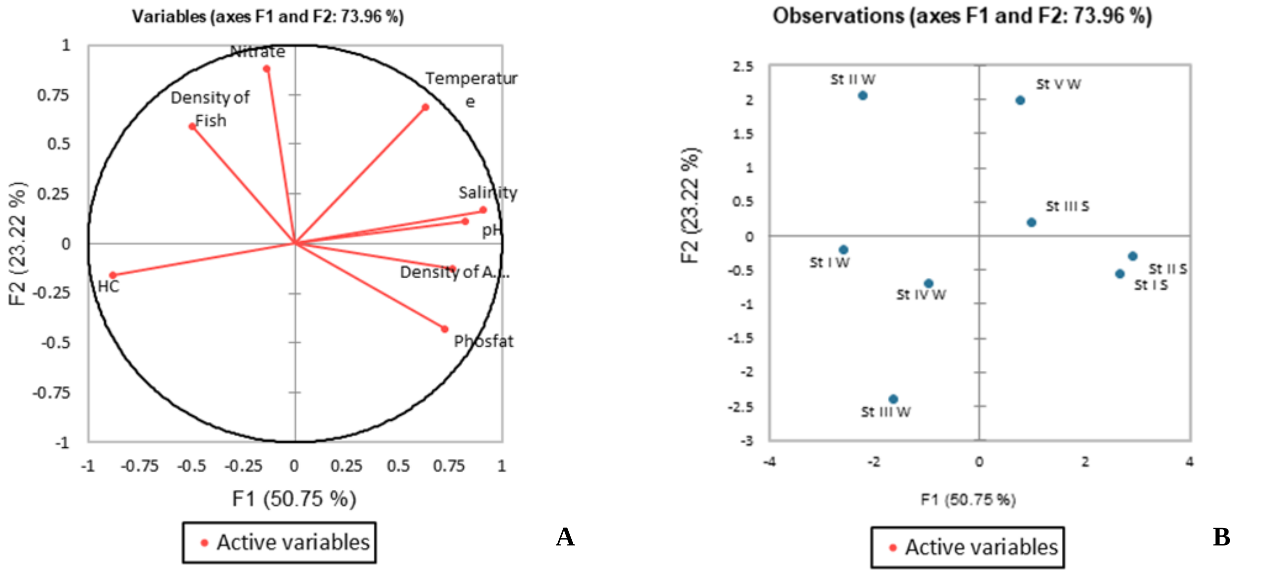

Figure 6. PCA analysis results. A. Ordination of environmental parameters on F1 and F2 axes; B. Representation of zone distribution based on environmental parameters on F1 and F2 axes

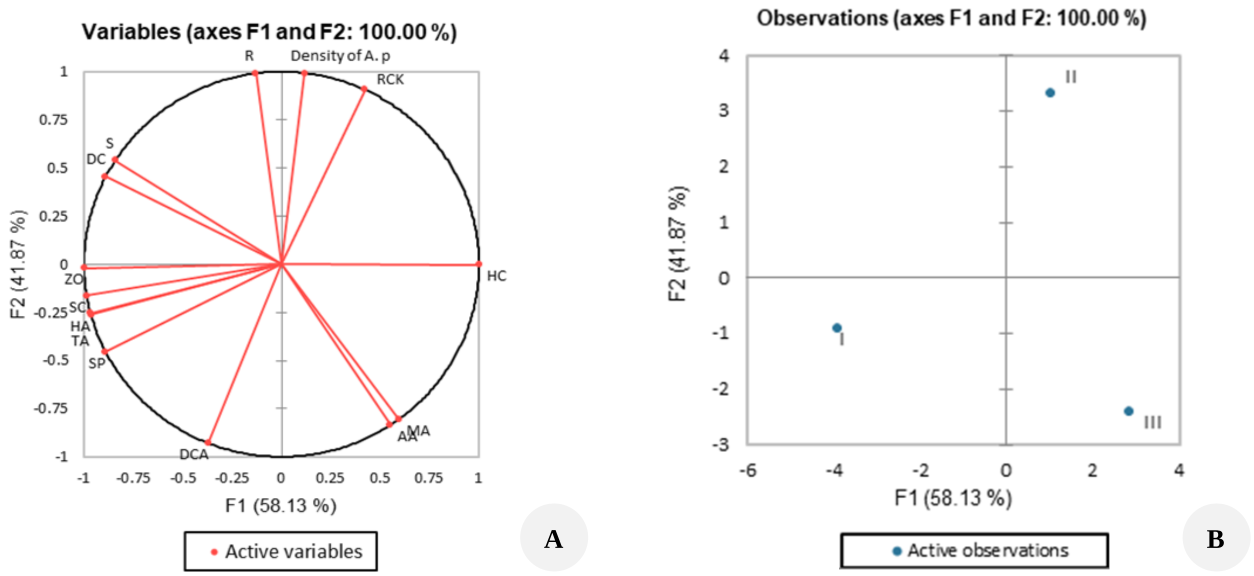

Figure 7. PCA analysis results. A. Ordination of coral cover composition on F1 and F2 axes; B. Representation of zone distribution based on coral cover composition on F1 and F2 axes

In conclusion, the research findings highlight the need for further investigation into the condition of coral cover on the Wakatobi Islands, which is better than on the Sombori Islands. The coral fish community structure on the Wakatobi Islands is more abundant than on the Sombori Islands, suggesting the potential for future discoveries in marine conservation. *Acanthaster planci*, a species found only in the Sombori islands, exhibits the highest abundance on the south side of StS II with 117 individuals. The presence of *A. planci* on the Sombori Islands is influenced by environmental parameters such as pH, salinity, nitrate, and dead coral, which are higher than on the Wakatobi Islands. Nitrate, salinity, and pH are identified as potential environmental factors contributing to the presence of *A. planci* on the Sombori Islands. The components of coral cover on the Sombori Islands that have the potential to cause the high presence of *A. planci* are comprised of healthy hard coral, rocks, and coral fractures. The high component of coral faults also has the potential to cause the presence and abundance of *A. planci* in the Sombori Islands to be higher because coral faults are a habitat for *A. planci* juveniles. The area where *A. planci* has a high rock and sand component, making it easier for *A. planci* to move towards the target reef. The high number of *A. planci* in the Sombori Islands is also accompanied by a low number of predatory *A. planci* fish, suggesting the need for further research into the causes of the high number of *A. planci* in the Sombori Islands.

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