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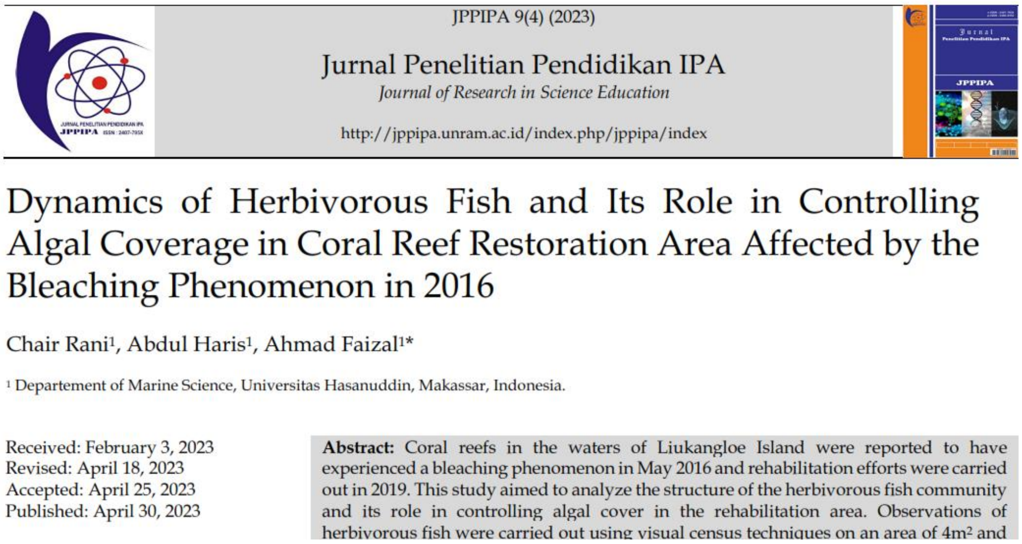

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Abstract: Coral reefs in the waters of Liukangloe Island were reported to have experienced a bleaching phenomenon in May 2016 and rehabilitation efforts were carried out in 2019. This study aimed to analyze the structure of the herbivorous fish community and its role in controlling algal cover in the rehabilitation area. Observations of herbivorous fish were carried out using visual census techniques on an area of 4m^2 and observation of algae in 0.5x0.5 m^2 transects on several coral attachment media from dead coral substrates. The results showed that the proportion of herbivorous fish species in the transplant area ranged from 15.81-58.67% and the proportion of individuals ranged from 12.51-34.62%. The dynamics of the number of species and abundance of herbivorous reef fish did not show significant differences between substrates and had the same dynamic pattern in all substrates uses but varied temporally according to the time of observation. The exception is the rubble area which continues to increase until the end of the observation. A high number of herbivorous fish species richness was observed in the branching and natural coral substrates and low in the rubble substrate. The abundance of herbivorous reef fish showed a significant and negative relationship to algal cover and confirmed that the presence of herbivorous reef fish could control or reduce the value of algal cover.

Keywords: Algae; Coral reefs; Herbivorous fish; Liukangloe island

Introduction

The coral bleaching incident in May 2016 on the coral reefs of Liukangloe Island caused coral bleaching of> 50% and caused coral reef damage of> 40% (Nirwan et al., 2017). The results of monitoring the impact of bleaching in 2017 found that at a depth of 3-5m, the impact of bleaching was high and occurred at all observation points with coral mortality of 35-60%(Rani et al., 2020). The event of coral bleaching has caused coral death and changed the basic structure of coral reefs. These changes will have an impact on associated biota, including a decrease in the wealth and abundance of reef fish, and can trigger macroalgae growth due to the availability of substrate in the form of dead coral. In addition, the decline in the population of herbivorous animals, including herbivorous fish, is also the cause of the increased abundance of algae and the increasing space competition between algae and corals (Couch et al., 2017; Ateweberhan et al., 2013; Cure et al., 2021; Tebbett et al., 2023).

Reef fish whose lives are related to coral reefs, the damage or decline in the condition of coral reefs naturally affects the diversity and abundance of reef fish. According to Elvan Ampou et al., (2017), disturbances that occur on coral reefs over a longer period (annual) may lead to lower fish abundance and diversity.

The interaction between algae and coral is one part of the ecological process. Algae as primary producers become one of the energy contributors for most herbivorous animals on coral reefs. However, algae are also major competitors for space with corals and may change the balance of coral reefs when their presence predominates. Algae growth is classified as very fast so it can be used as an indicator that affects populations

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and communities of various coral reef biota (Maududi & Luthfi, 2018).

In relation to algae in coral reef ecosystems, herbivorous fish are the main factors influencing changes in algal communities (Faizal et al., 2012). Herbivorous fish are the main controlling component of macroalgae growth with a functional role as direct consumers eg., grazers, macroalgae herbivores, scrapers target different type of algae and have differential impact on the algae growth control (Pombo-Ayora et al., 2020). The grazing activity of herbivorous fish is very important in creating open spaces for corals to settle and increasing coral recruitment by reducing algal cover (Bridge et al., 2013; Davies et al., 2013; Frimanozi et al., 2019). In addition, Elma et al., (2023) stated that the composition of herbivorous reef fish can control the presence of algae distribution in coral reef resilience.

Concerning the bleaching phenomenon in 2016 on the coral reefs of Liukangloe Island, in 2019, research was carried out on coral reef restoration techniques through the use of various dead coral substrate media that were still intact by bleaching events as attachment media for coral transplantation. This study proved that the use of branching, massive, and tabulated dead coral media was equally effective in supporting the growth of transplanted corals and did not show differences in growth from natural corals as controls for several coral species tested (Rani et al., 2020). Therefore, it is necessary to study the dynamics of the herbivorous reef fish community structure and its role in controlling algae cover in coral reef rehabilitation areas.

Method

Study Area

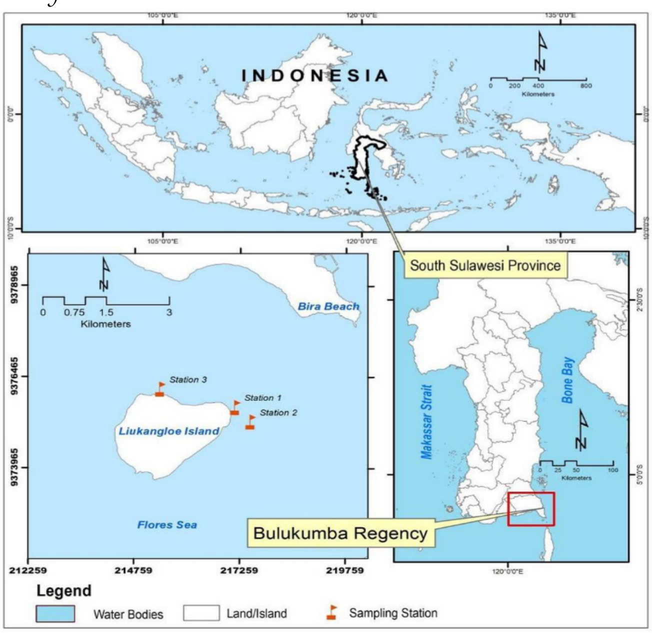

Figure 1. Map of sampling sites in the waters off the west coast of South Sulawesi

This research was conducted in the coral reef rehabilitation area that experienced bleaching in 2016 on the coral reefs of Liukangloe Island, Bulukumba Regency. The research was carried out for 5 months, from May to September 2021. In this study, 2 research stations were set on the north and east sides of the island. The main consideration is the number of bleaching events at that location. At Station 1, there are three deployment areas, while Stations 2 and 3 have only one deployment area each (a total of 5 deployment areas). In each placement area, there are three observation points according to the substrate media used in coral transplantation activities.

Media of Coral Transplant

Restoration of coral reefs with transplantation techniques is carried out by the attachment method using natural substrates in the form of dead coral that is still intact. Infrequently dead substrate media used were in the form of branching, massive, and tabulated substrates. As for the technical use of dead coral substrate as attachment media, namely 1) Branching coral substrate: Transplant coral fragments are tied to the branch ends of the natural substrate using cable ties; 2) Massive coral substrate: The transplanted coral fragments are attached to nails using a plastic cable (cable tie) before the nails are attached to the dead coral skeleton substrate; and 3) Tabulate coral substrate: selected colonies with large branching structures and still intact. The transplanted coral fragments were tied to the large branches using cable ties (Figure 2).

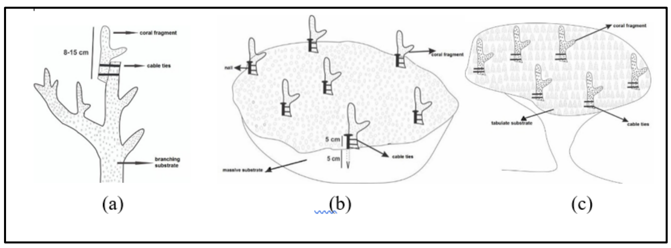

Figure 2. The dead coral substrate is used as an attachment medium for transplanted coral fragments in transplantation activities; (a) branching coral; (b) massive coral; and (c) tabulate coral.

Substrate treatment for attachment media was repeated 5 times in 5 treatment areas in an area of 4 m2 at a depth of 3-5 m. In each of these techniques, 10 coral fragments were transplanted per test coral species (*Acropora nobilis, Acropora formosa,* and *Porites cylindrica*) or 30 fragments per experimental unit. Placement points for the attachment of 30 fragments for all types of test corals were carried out randomly with a spacing of 20 cm. The transplanted coral fragments were measured for changes in branch length using calipers every month for 5 months of the study, and at the end of the study, the survival rate of each type of coral was also calculated.

The results showed that the three media used showed their effectiveness in supporting the growth of transplanted coral fragments tested and were as good as natural coral growth, while success in the survival parameters, the use of dead and branching coral media gave better results than tabulate corals (Rani et al., 2020).

Method Samples Collection

The algal cover was observed by placing a quadrant in the transplant area in each experimental unit using the dead coral substrate. The observation point is marked in the form of a float to facilitate the placement of the quadrant during subsequent observations. The assessment of the percentage of algal cover used a method that was modified by Faizal et al., 2012; Fabricius et al., 2023. The quadrant used is 05 x 0.5 m2 with a lattice of 10 x 10 cm^2. The cover unit category for each lattice is used on a scale of ¼, ½, ¾, and 1 unit. The area of algal cover in the quadrant grid was recorded in unit cover values and pictures were taken.

Observations of reef fish in each experimental unit were carried out using the stationary visual census technique, i.e., the reef fish present in the area (2m x 2m = $4m^2$) were recorded for the species and the number of individuals by staying silent in the center of the observation area. Identification of reef fish was carried out following the instructions (Allen et al., 1999).

Observations of coral reef fish and algae cover were also carried out in non-transplanted areas as a control on damaged coral reef areas, dominated by rubble and natural coral areas. The observation area is the same as the observation area in the transplanted area (4 m^2) and it is also repeated 5 times.

Data Analysis

Assessment of herbivorous reef fish community structure, i.e., the proportion of herbivorous fish to the total number of reef fish (number of species and number of individuals) in each treatment using substrate and control areas were analyzed descriptively with the help of graphs. The monthly dynamics of algae and herbivorous fish were also analyzed descriptively with the help of line graphs.

Differences in species richness and abundance of herbivorous fish between the use of dead coral substrates (including controls in the form of rubble-based substrates and natural coral) were analyzed using analysis of variance (one-way ANOVA), the number of replicates of each substrate was 5 times. Analysis of variance was carried out for each month of observation (May to September 2021). The results of the analysis are presented in graphical form. The analysis of the role of herbivorous reef fish in controlling algae cover was carried out by plotting the abundance of herbivorous reef fish with algae cover values in a scatter graph, while the relationship between algae cover and herbivorous fish abundance was analyzed by regression analysis.

Result and Discussion

The dynamics of changes in the community structure of herbivorous reef fish and their role in controlling algae cover during the 5 months of observation showed monthly variations in each experimental unit in the use of dead coral substrate as attachment media and also in control areas.

Herbivorous Fish Community Structure

The proportions of the presence of herbivorous reef fish in each treatment medium during the 5 months of observation are presented in Figures 3 and 4.

The proportion of herbivorous fish based on the number of reef fish species varied between dead coral substrates as transplantation media and also varied according to the month of observation. The magnitude of the variation ranges from 15.81 to 58.67% and depends on the substrate media used. The low proportion of herbivorous fish was found in natural coral (15.81-26.93%) and the highest in the control area in the form of rubble substrate (30-58.67%) and branching substrate (25.6-53.67%). As for the massive substrate, it is relatively the same as the tabulated substrate.

Monthly dynamics of the proportion of the number of herbivorous species in each substrate and control fluctuated in a low value or could be said to be stable, except in rubble and branching areas with high dynamics. In the rubble area, it continued to increase with a high percentage in July until the end of the observation, and in the branching substrate which increased rapidly in August after experiencing a decrease in July.

The results showed that the high proportion of herbivorous fish species in the rubble area was caused by the availability of algae or macroalgae at the bottom of the waters. According to Burkepile & Hay, (2011), the abundance of herbivorous reef fish is related to food and water conditions. Herbivorous reef fish are generally predators of benthic algae, so their distribution is determined by the presence of groups of benthic algae. The results of the research by Wibowo et al., (2016) showed that the number of species and abundance of herbivorous reef fish were positively correlated with the number of genera and density of young coral colonies recruited as a result of the grazing process of herbivorous reef fish.

Based on the number of individuals, the proportion of herbivorous fish ranged from 12.51 to 34.62%. A high proportion of herbivorous fish individuals was observed in the control area, namely on rubble and natural coral substrates. While the low in the other 3 substrates (branching, massive, and tabulate) ranged from 12 – 20%

(Figure 4). Monthly dynamics, experience small fluctuations or can be said to be stable throughout the observations. The exception for the control substrate was rubble, which experienced a fairly large increase in August, but decreased again as in the early observations.

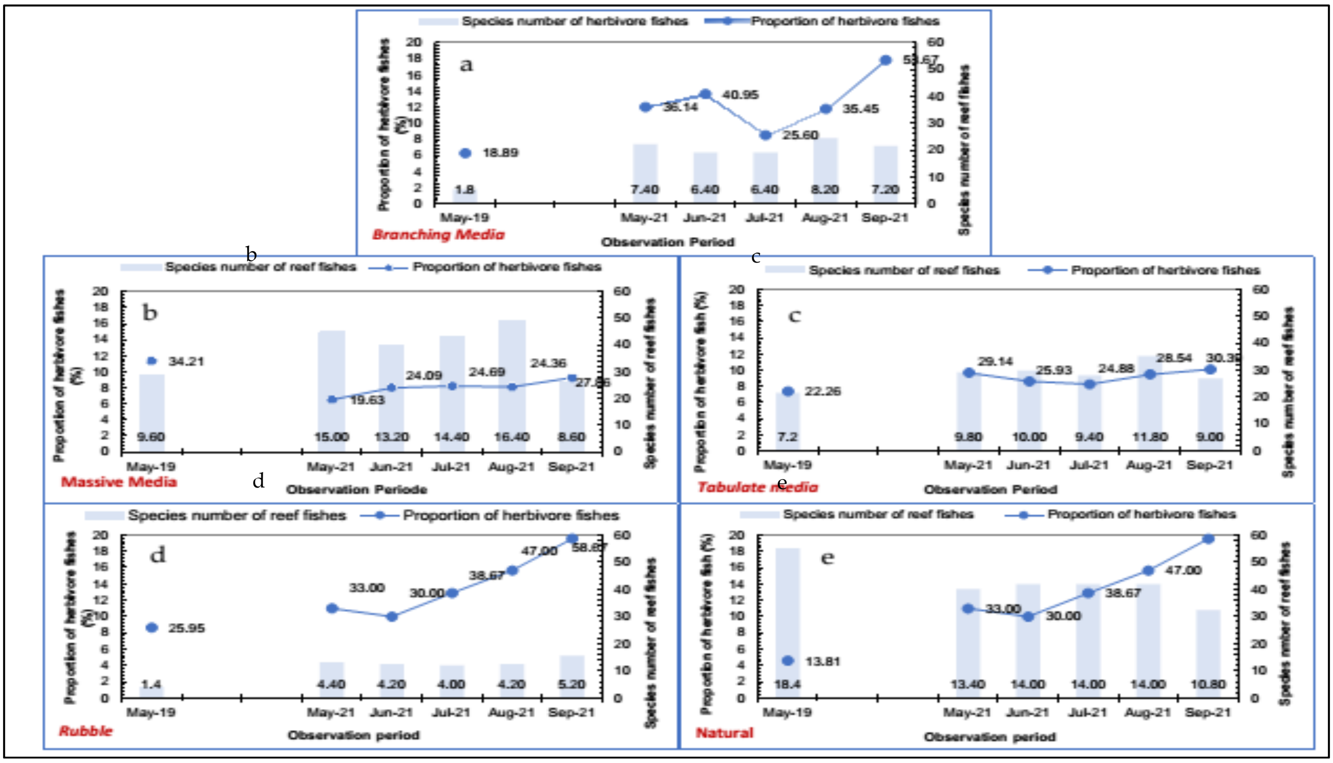

Figure 3. The dynamics of the proportion of the number of herbivorous reef fish species to the number of reef fish species on various transplant media for 5 months of observation; (a) branching media; (b) massive media; (c) tabulate media; (d) rubble; and (e) natural.

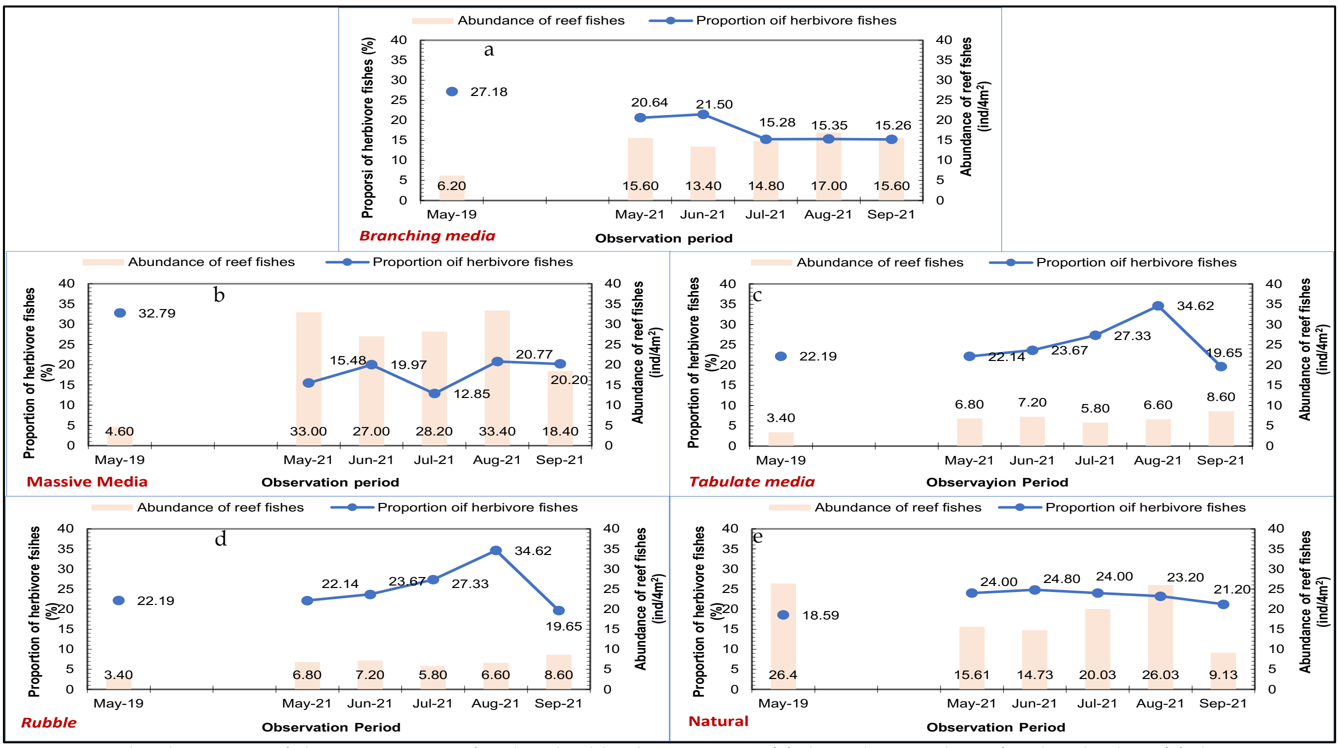

Figure 4. The dynamics of the proportion of individual herbivorous reef fish to the number of individual reef fish on various transplant media for 5 months of observation; (a) branching media; (b) massive media; (c) tabulate media; (d) rubble; and (e) natural.

The number of individuals and the proportion of herbivorous fish in the waters of Liukang Loe tends to be stable, this may be due to water conditions and water quality which tend to be uniform. According to Rani et al. (2020) under the same conditions of water quality and environment, the number of individual herbivorous fish may also be the same. Elma et al. (2023) research shows that the better the brightness, the more abundance of herbivorous reef fish will be. This is due to the influence of topography and depth which provides healthier ecological conditions.

Although it tends to be stable on each type of substrate, the presence of this herbivorous fish also shows a different proportion in each type of substrate. This difference is caused by the abundance of herbivorous reef fish related to food and water conditions. Herbivorous reef fish are generally predators of benthic algae, so their distribution is related to the presence of certain groups of algae. For example, the abundance of the scrapers group will be different from that of the browser's group which indicates a difference in the distribution of the algae group consumed or preferred (Burkepile & Hay, 2011). Figure 4 also shows that there is a change in the number of individuals from each observation point from time to time. This change is also one of the bioindicators of coral ecosystem health (Cole et al., 2008; Chou & Huang, 2021). Herbivorous fish are the indicator fish to control the growth of algae that can inhibit the recruitment of new corals (Cure et al., 2021; Chou & Huang, 2021).

Diversity and Abundance of Coral Fish

The diversity and abundance of herbivorous reef fish are one of the main components and play an important role in coral reef ecology. Its existence is very dynamic in space and time and is closely related to the dynamics of algae cover as its main food. The results of observations on various transplant media using dead coral substrate during the 5 months of observation and at the beginning of the study are presented in Figure 5.

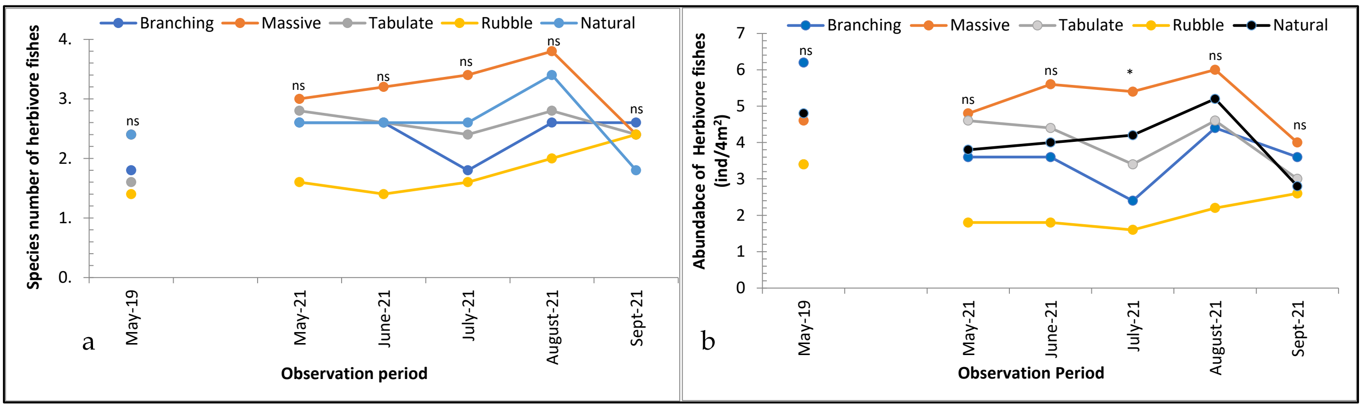

Figure 5. The dynamics of species richness (a) and abundance of herbivorous reef fish (b) on various dead coral substrates as attachment media in coral transplantation for 5 months of observation. ns: not significantly different

The spatial and temporal dynamics of the number and abundance of herbivorous reef fish have dynamics that vary greatly in temporal terms. Species richness and abundance of herbivorous reef fish had the same pattern of change in all substrates, including controls. It decreased in July and increased rapidly in August and then declined again in September (Figure 5 and Table 2). The exception is the rubble area which continues to increase until the end of the observation.

High herbivorous fish species richness was observed in branching and natural coral substrates and low in rubble substrates. Acanthuridae is a family of herbivorous fish that has the greatest number of species found (7 species) and for families Scaridae and Siganidae there are only 2 species each (Table 1 and Table 2).

Based on the abundance of herbivorous fish, massive substrate, tabulate, and natural coral had the highest abundance, and the lowest was found in the rubble area (Figure 5 and Table 1). The herbivorous fish species with the most common distribution based on the coral substrate and the month of observation were *Acanthurus nigricans, Ctenochaetus striatus*, and *Sebrasoma scopas*. However, the results of the analysis of variance showed that the number of species and abundance of herbivorous reef fish between dead coral substrates (including control in the form of rubble and natural coral) in each month of observation did not show a significant difference ($p > 0.05$), except for observations in July, it was found that there was a difference in the abundance of herbivorous fish ($p < 0.05$). No significant differences in the number of species and abundance of herbivorous reef fish were also observed at the start of the study (before transplant, in May 2019). The results of the analysis of variance for the number of species and abundance of herbivorous reef fish are presented in Table 3 and Table 4.

Table 1. Distribution of Individual Herbivorous Reef Fish on Various Dead Coral Substrates for Attachment Media for Transplanted Coral Fragments

Family	Species	Coral Dead Substrates				
		Branching	Massive	Tabulate	Rubble	Natural
Achanturidae	*Acanthurus leucosternon*	1				
	A. lineatus	1		1		
	A.pyropherus	3				1
	A.nigricans	12	32	12	8	17
	Naso lituratus	2	2			1
	Ctenochaetus striatus	26	37	39	22	24
	Zebrasoma scopas	26	33	30	6	27
Scaridae	*Chlorurus microrhinos*		6		0	2
	Scarus sp	3	12		8	7
Siganidae	*Siganus virgatus*	9	4	7	2	5
	Siganus vulpinus	5	3	11	4	16
Total		88	129	100	50	100

Table 2. Distribution of hHerbivorous Reef Fish Individuals by Month of Observation in the Transplant Area

Family	Species	Observation Period				
		May	June	July	August	September
Achanturidae	*Acanthurus leucosternon*	1				
	A. lineatus	1	1			
	A.pyropherus	2			1	1
	A.nigricans	18	15	17	20	11
	Naso lituratus				1	4
	Ctenochaetus striatus	33	27	29	35	24
	Zebrasoma scopas	24	31	25	30	12
Scaridae	*Chlorurus microrhinos*	1	1	1	1	4
	Scarus sp	5	7	4	8	6
Siganidae	*Siganus virgatus*	2	4	4	7	10
	Siganus vulpinus	6	11	5	9	8
Total		93	97	85	112	80

Table 3. Results of the Analysis of Variance on the Species Richness of Herbivorous Reef Fish Between Substrate Use in Each Observation Period

Observation Period	Source of Variation	Sum of Squares	df	Mean Square	F	Sig.
May 2019	Between Groups	4.24	4	1.06	1.83	0.16
	Within Groups	11.6	20	0.58		
	Total	15.84	24			
May 2021	Between Groups	5.84	4	1.46	1.30	0.30
	Within Groups	2.,4	20	1.12		
	Total	28.24	24			
June 2021	Between Groups	8.64	4	2.16	1.29	0.31
	Within Groups	33.6	20	1.68		
	Total	42.24	24			
July 2021	Between Groups	10.16	4	2.54	1.84	0.16
	Within Groups	27.6	20	1.38		
	Total	37.76	24			
August 2021	Between Groups	9.84	4	2.46	2.46	0.08
	Within Groups	20	20	1		
	Total	29.84	24			
September 2021	Between Groups	1.84	4	0.46	0.43	0.79
	Within Groups	21.6	20	1.08		
	Total	23.44	24			

Table 4. The Results of the Analysis of Variance on the Abundance of Herbivorous Reef Fish Between Substrate Uses in Each Observation Period

Observation Period	Source of Variation	Sum of Squares	df	Mean Square	F	Sig.
May 2019	Between Groups	27.04	4	6.76	1.59	0.22
	Within Groups	85.2	20	4.26		
	Total	112.24	24			
May 2021	Between Groups	28.24	4	7.06	2.11	0.12
	Within Groups	66.8	20	3.34		
	Total	95.04	24			
June 2021	Between Groups	38.24	4	9.56	1.90	0.15
	Within Groups	100.4	20	5.02		
	Total	138.64	24			
July 2021	Between Groups	44.4	4	11.1	3.49	0.03
	Within Groups	63.6	20	3.18		
	Total	108	24			
August 2021	Between Groups	40.24	4	10.06	2.29	0.10
	Within Groups	88	20	4.4		
	Total	128.24	24			
September 2021	Between Groups	6.8	4	1.7	0.51	0.73
	Within Groups	67.2	20	3.36		
	Total	74	24			

The distribution of herbivorous reef fish both based on the substrate and the month of observation as shown in Table 1 and Table 2, shows that the families Achanturidae and Siganidae were found in each type of substrate. The Siganidae family is a family of herbivorous reef fish that are selective in choosing their food and usually live in shallow waters (Sale, 2013). This family prefers macroalgae that have wide sheets like turf algae so that the fish can tear them easily. Turf algae are the dominant macroalgae group in coral reef ecosystems (Sale, 2013; Ellis et al., 2019).

During the observation period, herbivorous fish species from the families Acanthuridae (surgeonfish), Scaridae (parrotfish), and Siganidae (rabbitfish) were found in various transplanted substrates. The results of this study confirm various similar studies in tropical waters (Tomascik & Mah, 2013). For example, similar cases were reported from San Blas Islands Panama, and Ambergris Caye, Belize with Kyposiadae composition having the same proportions as Acanthuridae, Scaridae, and Siganidae (Williams et al., 2001). Similarly, reports from subtropical waters such as the Great Barrier Reef (Cooper et al., 2019) in the waters of Lizard Island with a composition of herbivorous fish abundance for Acanthuridae 54%, Scaridae 31%, and Siganidae (14%) (Zarco-Perello et al., 2019).

The highest herbivorous reef fish species found on various substrates during the study were *Ctenochaetus striatus, Zebrasoma scopas* and *Siganus vulpinus*. This species comes from the family Achanturidae and Siganidae. Both families dominated all substrates in each observation period. On the coral reefs of Nymph Island and Turtle Group, GBR, fish from the family Achanturidae were the most important herbivores (Brandl et al., 2019), while the family Siganidae were reported to be important herbivorous fish on coral reefs in Pioneer Bay, Orpheus Island (Thépot et al., 2021).

The Role of Herbivorous Reef Fish in Controlling Algal Cover

Herbivorous reef fish have a very important role in the stability of the ecosystem on coral reefs. One of its roles is to control the development of algae on hard substrates through a grazing mechanism so that it opens or provides a clean space for associated biota, including corals to attach or colonize. The role of herbivorous fish, in this case, their abundance on algal development, can be studied by observing the value of algal cover in each transplanted substrate every month and associated with the abundance of herbivorous reef fish, as shown in Figure 6.

In general, it shows a pattern of decreasing algal cover value with increasing herbivorous reef fish abundance or conversely increasing algal cover value when herbivorous fish abundance decreases. This pattern is visible in the control area (rubble and natural coral) and the massive substrate. The pattern in Figure 6 indicated that the association was confirmed by simple regression analysis of the relationship between the abundance of herbivorous reef fish as the X-Axis and the value of algal cover as the Y Source (Figure 7).

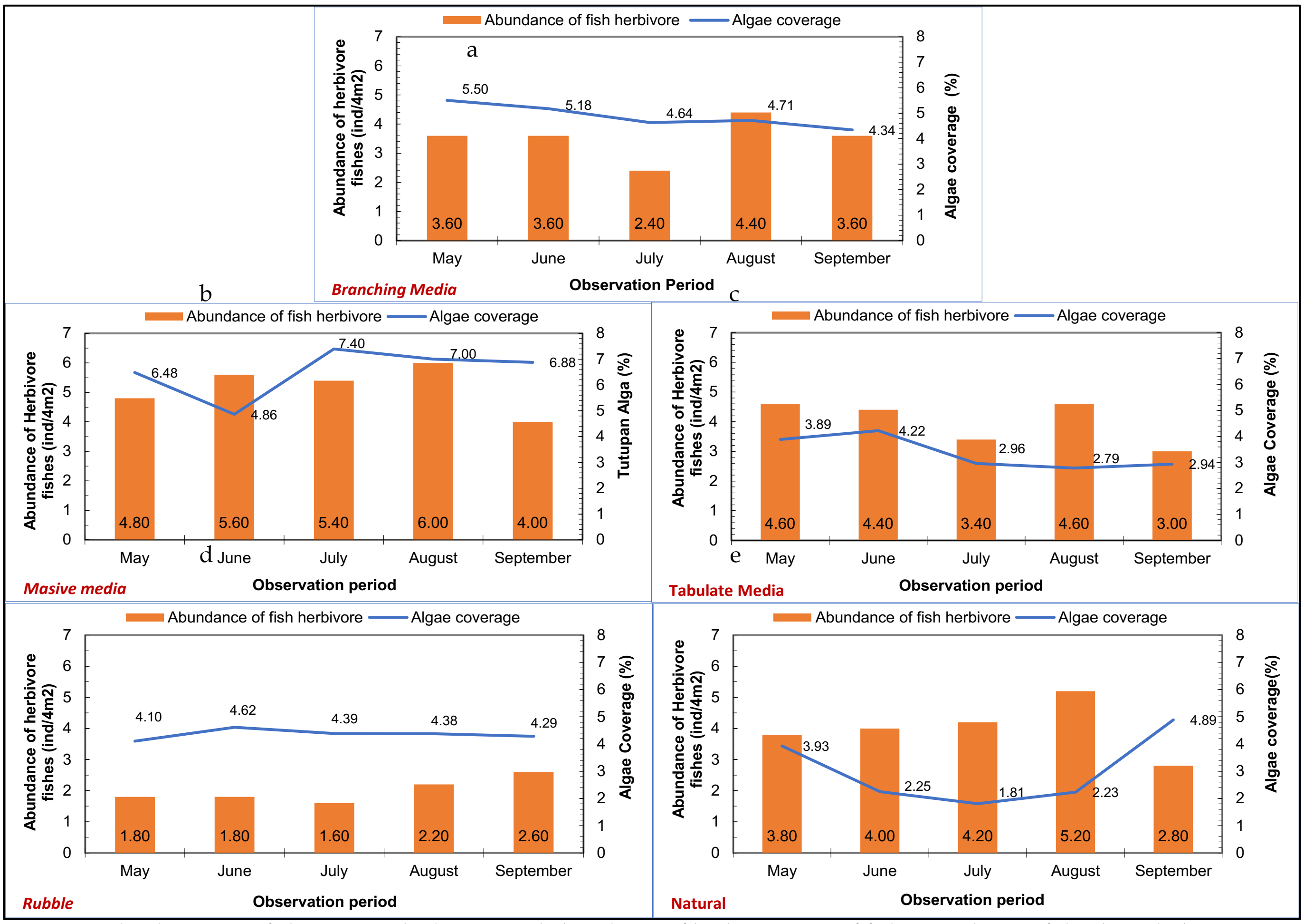

Figure 6. The dynamics of changes in algal cover and abundance of herbivorous reef fish on each use of dead coral ubstrate as a medium for attachment of coral fragments in transplantation activities for 5 months of observation; (a) branching media; (b) massive media; (c) tabulate media; (d) rubble; and (e) natural

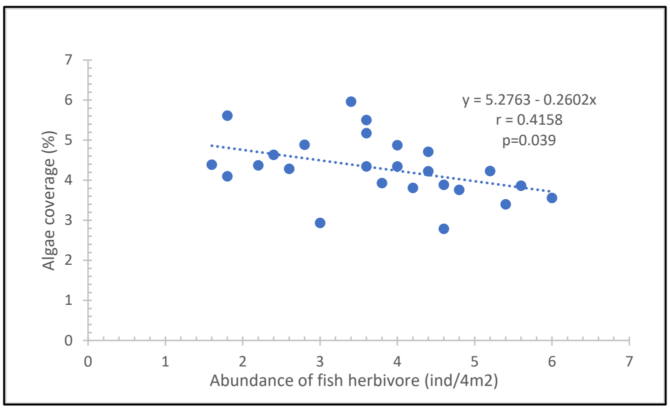

Figure 7. Scatter diagram of the relationship between herbivorous reef fish abundance and algal cover on various uses of the dead coral substrate

The results of the regression analysis give the equation y: 5.2763-0.260x with a correlation value of 0.4158. The regression equation proves that there is a linear relationship between the abundance of herbivorous fish and algal cover with a strength value of 41.58% and the relationship is negative. In the sense that an increase in the abundance of herbivorous reef fish will reduce the value of algal cover. Each increase in herbivorous fish by 1 individual will reduce algal cover by 0.26% in the transplant area. This relationship is significantly correlated based on the results of the analysis of variance with a probability value of 0.039 ($p < 0.05$).

The results of this study indicate that herbivorous fish is one of the factors that can control the high macroalgae cover in coral reef waters. Any reduction in herbivorous fish in sufficient nutrient conditions will cause an increase in macroalgae cover in the waters. This is in line with Zarco-Perello et al. (2019) research that the presence of herbivorous fish can be a savior of certain corals from macroalgae aggression. In the Great Barrier Reef, with the experiment, the macroalga *Sargassum siliquosum* transplanted on the reef flat did not grow well if it was confined to herbivorous fish. This study proves that the high abundance of herbivorous fish is a limiting factor in the distribution of these macroalgae. Another study in Jamaica found that by limiting the fishing of herbivores in the period 1996-1999, the result could reduce the percentage of macroalgae cover from 60% to 10%. In eutrophic water conditions, the role of herbivorous fish is very important in maintaining corals in competition with macroalgae (Williams et al., 2001).

High macroalgae growth can be controlled by the presence of herbivorous fish (Goreau & Hayes, 2021). Herbivorous fish are the only mechanism controlling the growth of macroalgae in coral reefs. If the growth of macroalgae is not controlled, it will automatically dominate coral reefs (McCook, 2001). In high nutrient conditions, macroalgae growth develops rapidly so that it can cause a phase shift condition (macroalgae dominance over corals). In the end, corals lost in fighting for space and light, causing a decrease in metabolism and coral growth, but with the control of herbivorous fish, macroalgae growth conditions could be suppressed (Zarco-Perello et al., 2019; Ryanskiy, 2022).

Without the presence of herbivorous fish, the recovery of coral communities will be hampered by the dominance of macroalgae that quickly occupy the space left by the corals. The high role of herbivorous fish in coral reef ecosystems causes the need for restrictions on herbivorous fishing. Overexploitation will cause high algal growth (Johnson et al., 2019; Adam et al., 2022) and will eventually cause the percentage of coral cover to decrease and the mortality of young corals to increase. In addition, the abundance of herbivorous fish was positively correlated with the addition of young coral colonies through the recruitment process (Mumby et al., 2006).

Conclusion

The proportion of herbivorous fish species in the transplant area ranged from 15.81 to 58.67% and varied both based on the month of observation and the use of dead coral substrate as attachment media. The dynamics of the number of species and abundance of herbivorous reef fish had the same dynamic pattern in all dead coral substrates but varied temporally according to the time of observation. The relationship between algal cover and herbivorous reef fish abundance showed a negative and significant relationship which confirmed that the presence of herbivorous reef fish could control or reduce the value of algal cover.

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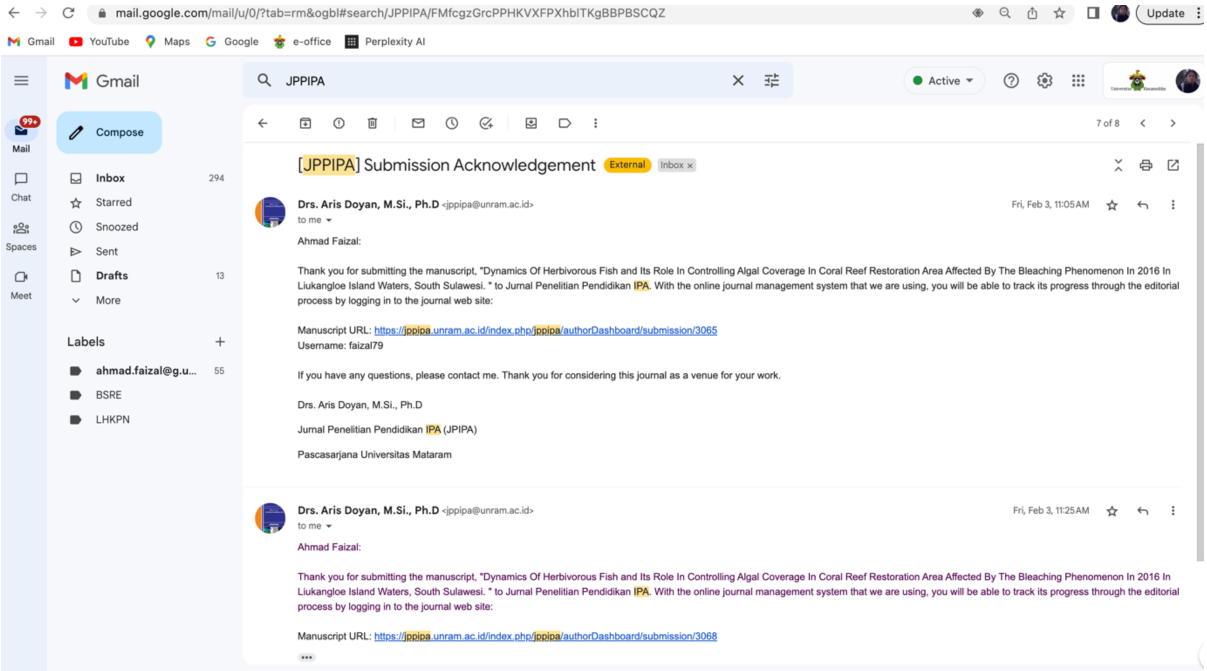

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Dynamics Of Herbivorous Fish and Its Role In Controlling Algal Coverage In Coral Reef Restoration Area Affected By The Bleaching Phenomenon In 2016 In Liukangloe Island Waters, South Sulawesi.

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Abstract: Coral reefs in the waters of Liukangloe Island were reported to have experienced a bleaching phenomenon in May 2016 and rehabilitation efforts were carried out in 2019. This study aimed to analyze the structure of the herbivorous fish community and its role in controlling algal cover in the rehabilitation area. Observations of herbivorous fish were carried out using visual census techniques on an area of $4m^2$ and observation of algae in $0.5x0.5\ m^2$ transects on several coral attachment media from dead coral substrates. The results showed that the proportion of herbivorous fish species in the transplant area ranged from 15.81 – 58.67% and the proportion of individuals ranged from 12.51 – 34.62%. The dynamics of the number of species and abundance of herbivorous reef fish did not show significant differences between substrates and had the same dynamic pattern in all substrate uses, but varied temporally according to the time of observation. The exception is the rubble area which continues to increase until the end of the observation. A high number of herbivorous fish species richness was observed in the branching and natural coral substrates and low in the rubble substrate. The abundance of herbivorous reef fish showed a significant and negative relationship to algal cover and confirmed that the presence of herbivorous reef fish could control or reduce the value of algal cover.

Keywords: Coral reefs, herbivorous fish, algae, Liukangloe Island.

Citation:

Introduction

The coral bleaching incident in May 2016 on the coral reefs of Liukangloe Island caused coral bleaching of> 50% and caused coral reef damage of> 40% (Nirwan, et al., 2017). The results of monitoring the impact of bleaching in 2017 found that at a depth of 3-5m, the impact of bleaching was high and occurred at all observation points with coral mortality of 35-60% (Rani et al., 2017). The event of coral bleaching has caused coral death and changed the basic structure of coral reefs. These changes will have an impact on associated biota, including a decrease in the wealth and abundance of reef fish, and can trigger macroalgae growth due to the availability of substrate in the form of dead coral. In addition, the decline in the population of herbivorous animals, including herbivorous fish, is also the cause of the increased abundance of algae and the increasing space competition between algae and corals (Glynn, 1993; Jompa & McCook, 2002; Ateweberhan et al., 2013 Couch et al., 2017)

Reef fish whose lives are related to coral reefs, the damage or decline in the condition of coral reefs naturally affects the diversity and abundance of reef fish. According to Ampou et al., (2017), disturbances that occur on coral reefs over a longer period (annual) may lead to lower fish abundance and diversity.

The interaction between algae and coral is one part of the ecological process. Algae as primary producers become one of the energy contributors for most herbivorous animals on coral reefs. However, algae are also major competitors for space with corals and may change the balance of coral reefs when their presence

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predominates. Algae growth is classified as very fast so it can be used as an indicator that affects populations and communities of various coral reef biota (Maududi & Luthfi, 2018).

In relation to algae in coral reef ecosystems, herbivorous fish are the main factors influencing changes in algal communities (Faizal *et al*., 2012). Herbivorous fish are the main controlling component of macroalgae growth with a functional role as direct consumers eg., grazers, macroalgae herbivores, scrapers target different type of algae and have differential impact on the algae growth control (Pombo-Ayora et. al., 2020). The grazing activity of herbivorous fish is very important in creating open spaces for corals to settle and increasing coral recruitment by reducing algal cover (Bridge *et al*., 2013; Davies, 2013; Frimanozi *et al*., 2019). In addition, Husain *et al*. (2013) stated that the composition of herbivorous reef fish can control the presence of algae distribution in coral reef resilience.

Concerning the bleaching phenomenon in 2016 on the coral reefs of Liukangloe Island, in 2019, research was carried out on coral reef restoration techniques through the use of various dead coral substrate media that were still intact by bleaching events as attachment media for coral transplantation. This study proved that the use of branching, massive, and tabulated dead coral media was equally effective in supporting the growth of transplanted corals and did not show differences in growth from natural corals as controls for several coral species tested (Rani et al., 2020). Therefore, it is necessary to study the dynamics of the herbivorous reef fish community structure and its role in controlling algae cover in coral reef rehabilitation areas.

Method

1. Study Area

This research was conducted in the coral reef rehabilitation area that experienced bleaching in 2016 on the coral reefs of Liukangloe Island, Bulukumba Regency. The research was carried out for 5 months, from May to September 2021. In this study, 2 research stations were set on the north and east sides of the island. The main consideration is the number of bleaching events at that location. At Station 1, there are three deployment areas, while Stations 2 and 3 have only one deployment area each (a total of 5 deployment areas). In each placement area, there are three observation points according to the substrate media used in coral transplantation activities.

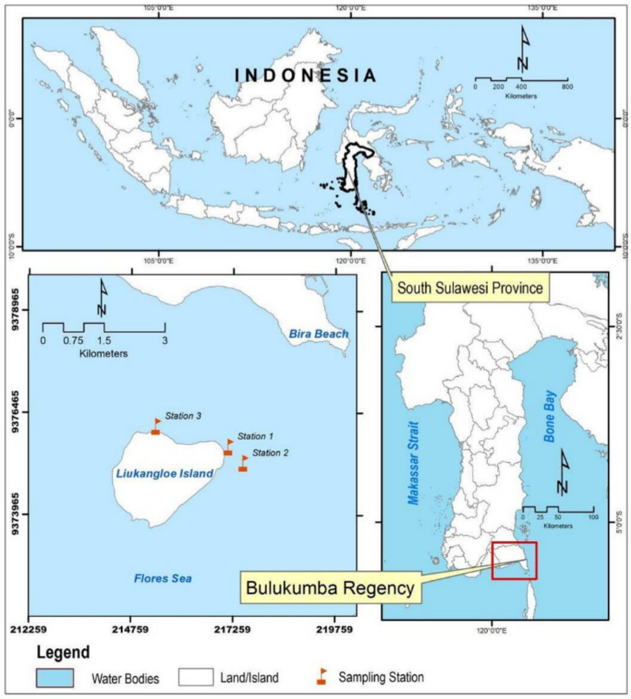

Figure 1. Map of sampling sites in the waters off the west coast of South Sulawesi

2. Media of Coral Transplant

Restoration of coral reefs with transplantation techniques is carried out by the attachment method using natural substrates in the form of dead coral that is still intact. Infrequently dead substrate media used were in the form of branching, massive, and tabulated substrates. As for the technical use of dead coral substrate as attachment media, namely 1) Branching coral substrate: Transplant coral fragments are tied to the branch ends of the natural substrate using cable ties; 2) Massive coral substrate: The transplanted coral fragments are attached to nails using a plastic cable (cable tie) before the nails are attached to the dead coral skeleton substrate; and 3) Tabulate coral substrate: selected colonies with large branching structures and still intact. The transplanted coral fragments were tied to the large branches using cable ties (Figure 2).

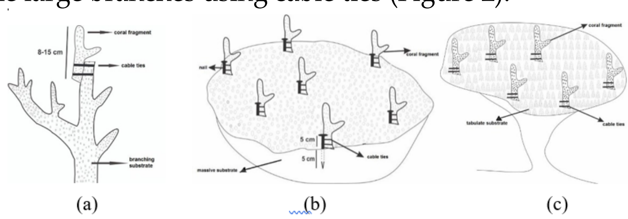

Figure 2. The dead coral substrate is used as an attachment medium for transplanted coral fragments in transplantation activities (a: branching coral; b: massive coral; and c: tabulate coral.

Substrate treatment for attachment media was repeated 5 times in 5 treatment areas in an area of 4 m2 at a depth of 3 - 5 m. In each of these techniques, 10 coral fragments were transplanted per test coral species (*Acropora nobilis, Acropora formosa,* and *Porites cylindrica*) or 30 fragments per experimental unit. Placement points for the attachment of 30 fragments for all types of test corals were carried out randomly with a spacing of 20 cm. The transplanted coral fragments were measured for changes in branch length using calipers every month for 5 months of the study, and at the end of the study, the survival rate of each type of coral was also calculated. The results showed that the three media used showed their effectiveness in supporting the growth of transplanted coral fragments tested and were as good as natural coral growth, while success in the survival parameters, the use of dead and branching coral media gave better results than tabulate corals (Rani et al., 2020)

3. Method Samples Collection

The algal cover was observed by placing a quadrant in the transplant area in each experimental unit using the dead coral substrate. The observation point is marked in the form of a float to facilitate the placement of the quadrant during subsequent observations. The assessment of the percentage of algal cover used a method that was modified by Faizal (2011; 2012). The quadrant used is 05 x 0.5 m2 with a lattice of 10 x 10 cm2. The cover unit category for each lattice is used on a scale of ¼, ½, ¾, and 1 unit. The area of algal cover in the quadrant grid was recorded in unit cover values and pictures were taken.

Observations of reef fish in each experimental unit were carried out using the stationary visual census technique, i.e., the reef fish present in the area (2m x 2m = $4m^2$) were recorded for the species and the number of individuals by staying silent in the center of the observation area. Identification of reef fish was carried out following the instructions of Allen (2000) and Kuiter & Tonozuka (2001).

Observations of coral reef fish and algae cover were also carried out in non-transplanted areas as a control on damaged coral reef areas, dominated by rubble and natural coral areas. The observation area is the same as the observation area in the transplanted area (4 m^2) and it is also repeated 5 times.

4. Data analysis

Assessment of herbivorous reef fish community structure, i.e., the proportion of herbivorous fish to the total number of reef fish (number of species and number of individuals) in each treatment using substrate and control areas were analyzed descriptively with the help of graphs. The monthly dynamics of algae and herbivorous fish were also analyzed descriptively with the help of line graphs.

Differences in species richness and abundance of herbivorous fish between the use of dead coral substrates (including controls in the form of rubble-based substrates and natural coral) were analyzed using analysis of variance (one-way ANOVA), the number of replicates of each substrate was 5 times. Analysis of variance was carried out for each month of observation (May to September 2021). The results of the analysis are presented in graphical form. The analysis of the role of herbivorous reef fish in controlling algae cover was carried out by plotting the abundance of herbivorous reef fish with algae cover values in a scatter graph, while the relationship between algae cover and herbivorous fish abundance was analyzed by regression analysis.

Result and Discussion

The dynamics of changes in the community structure of herbivorous reef fish and their role in controlling algae cover during the 5 months of observation showed monthly variations in each experimental unit in the use of dead coral substrate as attachment media and also in control areas.

1. Herbivorous Fish Community Structure

The proportions of the presence of herbivorous reef fish in each treatment medium during the 5 months of observation are presented in Figures 3 and 4.

The proportion of herbivorous fish based on the number of reef fish species varied between dead coral substrates as transplantation media and also varied according to the month of observation. The magnitude of the variation ranges from 15.81 to 58.67% and depends on the substrate media used. The low proportion of herbivorous fish was found in natural coral (15.81 – 26.93%) and the highest in the control area in the form of rubble substrate (30 -58.67%) and branching substrate (25.6 – 53.67%). As for the massive substrate, it is relatively the same as the tabulated substrate.

Monthly dynamics of the proportion of the number of herbivorous species in each substrate and control fluctuated in a low value or could be said to be stable, except in rubble and branching areas with high dynamics. In the rubble area, it continued to increase with a high percentage in July until the end of the observation, and in the branching substrate which increased rapidly in August after experiencing a decrease in July.

The results showed that the high proportion of herbivorous fish species in the rubble area was caused by the availability of algae or macroalgae at the bottom of the waters. According to Burkepile & Hay (2011), the abundance of herbivorous reef fish is related to food and water conditions. Herbivorous reef fish are generally predators of benthic algae, so their distribution is determined by the presence of groups of benthic algae. The results of the research by Wibowo et al. (2016) showed that the number of species and abundance of herbivorous reef fish were positively correlated with the number of genera and density of young coral colonies recruited as a result of the grazing process of herbivorous reef fish.

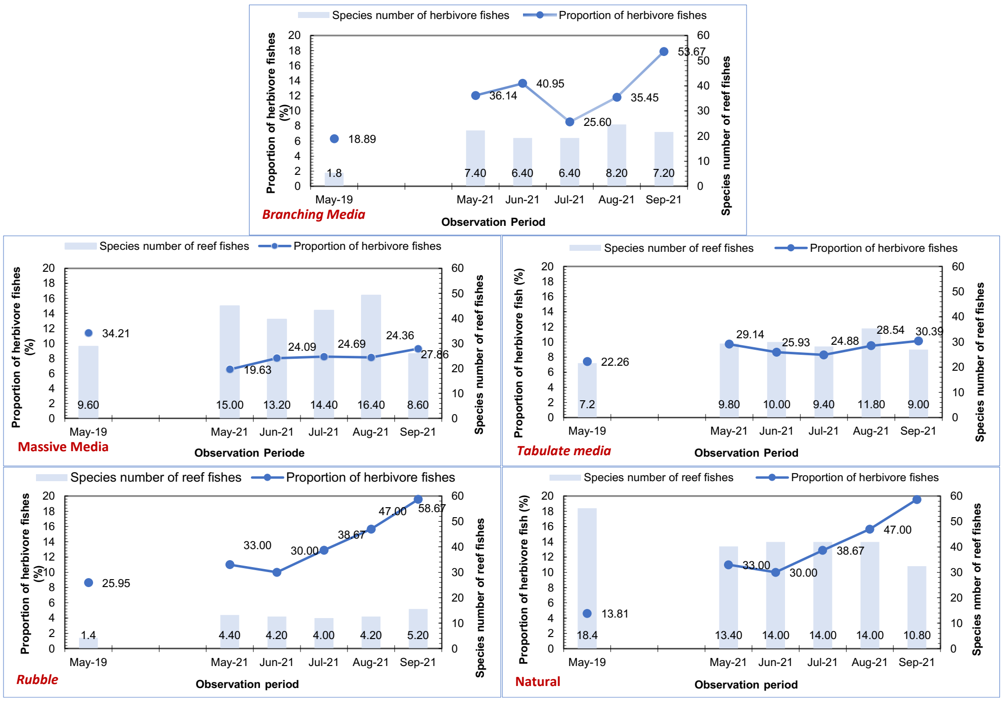

Figure 3. The dynamics of the proportion of the number of herbivorous reef fish species to the number of reef fish species on various transplant media for 5 months of observation.

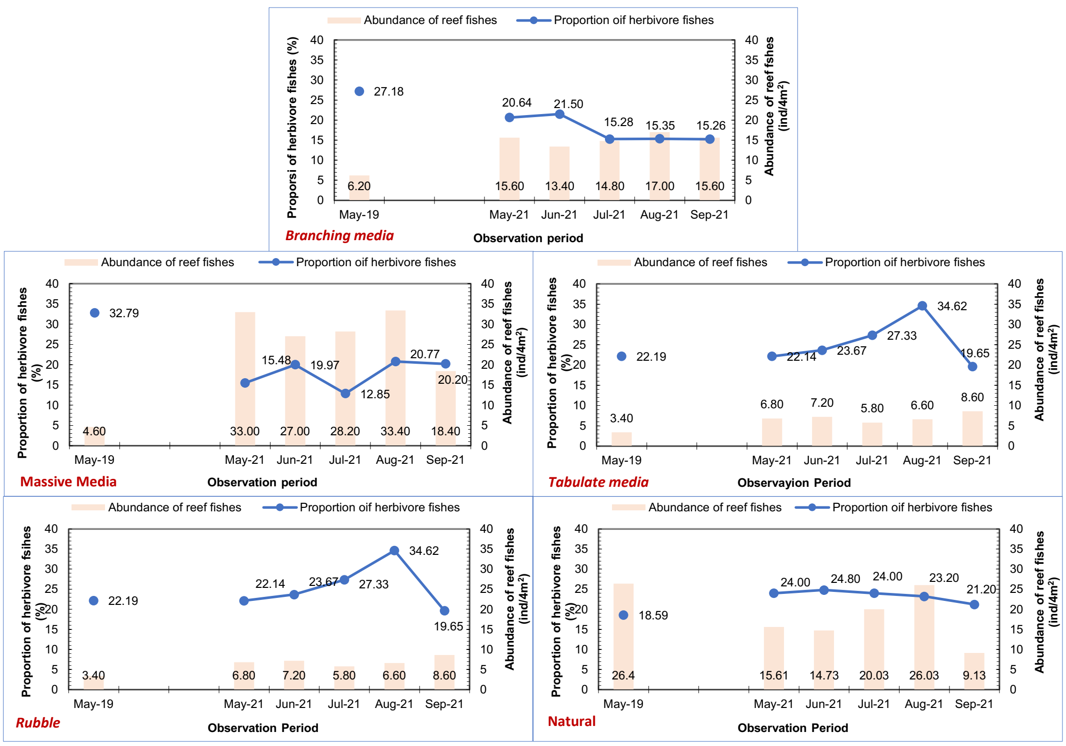

Figure 4. The dynamics of the proportion of individual herbivorous reef fish to the number of individual reef fish on various transplant media for 5 months of observation

Based on the number of individuals, the proportion of herbivorous fish ranged from 12.51 to 34.62%. A high proportion of herbivorous fish individuals was observed in the control area, namely on rubble and natural coral substrates. While the low in the other 3 substrates (branching, massive, and tabulate) ranged from 12 – 20% (Figure 4). Monthly dynamics, experience small fluctuations or can be said to be stable throughout the observations. The exception for the control substrate was rubble, which experienced a fairly large increase in August, but decreased again as in the early observations.

The number of individuals and the proportion of herbivorous fish in the waters of Liukang Loe tends to be stable, this may be due to water conditions and water quality which tend to be uniform. According to Rani et al., (2017), under the same conditions of water quality and environment, the number of individual herbivorous fish may also be the same. Husain (2012) research, shows that the better the brightness, the more abundance of herbivorous reef fish will be. This is due to the influence of topography and depth which provides healthier ecological conditions.

Although it tends to be stable on each type of substrate, the presence of this herbivorous fish also shows a different proportion in each type of substrate. This difference is caused by the abundance of herbivorous reef fish related to food and water conditions. Herbivorous reef fish are generally predators of benthic algae, so their distribution is related to the presence of certain groups of algae. For example, the abundance of the scrapers group will be different from that of the browser's group which indicates a difference in the distribution of the algae group consumed or preferred (Burkepile & Hay, 2011). Figure 4 also shows that there is a change in the number of individuals from each observation point from time to time. This change is also one of the bioindicators of coral ecosystem health (Cole et al., 2008; Obura & Grimsdith, 2009). Herbivorous fish are the indicator fish to control the growth of algae that can inhibit the recruitment of new corals (Green & Bellwood, 2009; Obura & Grimsdith, 2009).

2. Diversity and Abundance of Coral Fish

The diversity and abundance of herbivorous reef fish are one of the main components and play an important role in coral reef ecology. Its existence is very dynamic in space and time and is closely related to the dynamics of algae cover as its main food. The results of observations on various transplant media using dead coral substrate during the 5 months of observation and at the beginning of the study are presented in Figure 5.

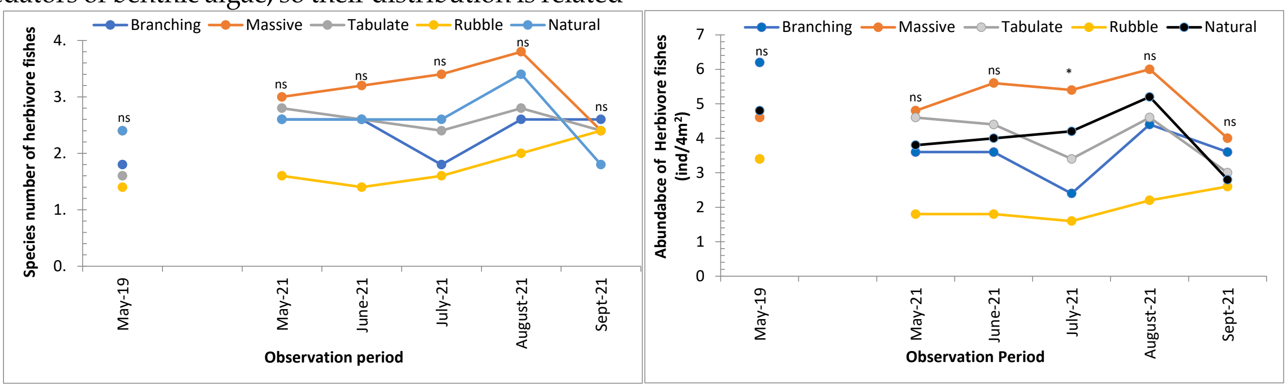

Figure 5. The dynamics of species richness (a) and abundance of herbivorous reef fish (b) on various dead coral substrates as attachment media in coral transplantation for 5 months of observation. ns: not significantly different

The spatial and temporal dynamics of the number and abundance of herbivorous reef fish have dynamics that vary greatly in temporal terms. Species richness and abundance of herbivorous reef fish had the same pattern of change in all substrates, including controls. It decreased in July and increased rapidly in August and then declined again in September (Figure 5 and Table 2). The exception is the rubble area which continues to increase until the end of the observation.

High herbivorous fish species richness was observed in branching and natural coral substrates and low in rubble substrates. Acanthuridae is a family of herbivorous fish that has the greatest number of species found (7 species) and for families Scaridae and Siganidae there are only 2 species each (Table 1 and Table 2).

Table 1. Distribution of individual herbivorous reef fish on various dead coral substrates for attachment media for transplanted coral fragments

Family	Species	Coral dead substrates				
		Branching	Massive	Tabulate	Rubble	Natural
Achanturidae	*Acanthurus leucosternon*	1	0	0	0	0
	A. lineatus	1	0	1	0	0
	A.pyropherus	3	0	0	0	1
	A.nigricans	12	32	12	8	17
	Naso lituratus	2	2	0	0	1
	Ctenochaetus striatus	26	37	39	22	24
	Zebrasoma scopas	26	33	30	6	27
Scaridae	*Chlorurus microrhinos*	0	6	0	0	2
	Scarus sp	3	12	0	8	7
Siganidae	*Siganus virgatus*	9	4	7	2	5
	Siganus vulpinus	5	3	11	4	16
	Total	**88**	**129**	**100**	**50**	**100**

Table 2. Distribution of herbivorous reef fish individuals by month of observation in the transplant area

Family	Species	Observation Period				
		May	June	July	August	September
Achanturidae	*Acanthurus leucosternon*	1				
	A. lineatus	1	1			
	A.pyropherus	2			1	1
	A.nigricans	18	15	17	20	11
	Naso lituratus				1	4
	Ctenochaetus striatus	33	27	29	35	24
	Zebrasoma scopas	24	31	25	30	12
Scaridae	*Chlorurus microrhinos*	1	1	1	1	4
	Scarus sp	5	7	4	8	6
Siganidae	*Siganus virgatus*	2	4	4	7	10
	Siganus vulpinus	6	11	5	9	8
	Total	**93**	**97**	**85**	**112**	**80**

Based on the abundance of herbivorous fish, massive substrate, tabulate, and natural coral had the highest abundance, and the lowest was found in the rubble area (Figure 5 and Table 1). The herbivorous fish species with the most common distribution based on the coral substrate and the month of observation were *Acanthurus nigricans, Ctenochaetus striatus*, and *Sebrasoma scopas*. However, the results of the analysis of variance showed that the number of species and abundance of herbivorous reef fish between dead coral substrates (including control in the form of rubble and natural coral) in each month of observation did not show a significant difference ($p > 0.05$), except for observations in July, it was found that there was a difference in the abundance of herbivorous fish ($p < 0.05$). No significant differences in the number of species and abundance of herbivorous reef fish were also observed at the start of the study (before transplant, in May 2019). The results of the analysis of variance for the number of species and abundance of herbivorous reef fish are presented in Table 3 and Table 4.

Table 3. Results of the analysis of variance on the species richness of herbivorous reef fish between substrate use in each observation period

Obervation Period	Source of Variation	Sum of Squares	df	Mean Square	F	Sig.
May 2019	Between Groups	4.24	4	1.06	1.83	0.16
	Within Groups	11.6	20	0.58		
	Total	15.84	24			
May 2021	Between Groups	5.84	4	1.46	1.30	0.30
	Within Groups	22.4	20	1.12		
	Total	28.24	24			
June 2021	Between Groups	8.64	4	2.16	1.29	0.31
	Within Groups	33.6	20	1.68		
	Total	42.24	24			
July 2021	Between Groups	10.16	4	2.54	1.84	0.16
	Within Groups	27.6	20	1.38		
	Total	37.76	24			
August 2021	Between Groups	9.84	4	2.46	2.46	0.08
	Within Groups	20	20	1		
	Total	29.84	24			
September 2021	Between Groups	1.84	4	0.46	0.43	0.79
	Within Groups	21.6	20	1.08		
	Total	23.44	24			

Table 4. The results of the analysis of variance on the abundance of herbivorous reef fish between substrate uses in each observation period

Obervation Period	Source of Variation	Sum of Squares	df	Mean Square	F	Sig.
May 2019	Between Groups	27.04	4	6.76	1.59	0.22
	Within Groups	85.2	20	4.26		
	Total	112.24	24			
May 2021	Between Groups	28.24	4	7.06	2.11	0.12
	Within Groups	66.8	20	3.34		
	Total	95.04	24			
June 2021	Between Groups	38.24	4	9.56	1.90	0.15
	Within Groups	100.4	20	5.02		
	Total	138.64	24			
July 2021	Between Groups	44.4	4	11.1	3.49	0.03
	Within Groups	63.6	20	3.18		
	Total	108	24			
August 2021	Between Groups	40.24	4	10.06	2.29	0.10
	Within Groups	88	20	4.4		
	Total	128.24	24			
September 2021	Between Groups	6.8	4	1.7	0.51	0.73
	Within Groups	67.2	20	3.36		
	Total	74	24			

The distribution of herbivorous reef fish both based on the substrate and the month of observation as shown in Table 1 and Table 2, shows that the families Achanturidae and Siganidae were found in each type of substrate. The Siganidae family is a family of herbivorous reef fish that are selective in choosing their food and usually live in shallow waters (Sale, 1991). This family prefers macroalgae that have wide sheets like turf algae so that the fish can tear them easily. Turf algae are the dominant macroalgae group in coral reef ecosystems (Sale, 1991; Jompa & McCook, 2003).

During the observation period, herbivorous fish species from the families Acanthuridae (surgeonfish), Scaridae (parrotfish), and Siganidae (rabbitfish) were found in various transplanted substrates. The results of this study confirm various similar studies in tropical waters (Tomascik et al., 1997). For example, similar cases were reported from San Blas Islands Panama, and Ambergris Caye, Belize with Kyposiadae composition having the same proportions as Acanthuridae, Scaridae, and Siganidae (William et al., 2001). Similarly, reports from subtropical waters such as the Great Barrier Reef (Russ, 1984) in the waters of Lizard Island with a composition of herbivorous fish abundance for

Acanthuridae 54%, Scaridae 31%, and Siganidae (14%) (Meekan & Choat, 1997).

The highest herbivorous reef fish species found on various substrates during the study were *Ctenochaetus striatus, Zebrasoma scopas* and *Siganus vulpinus*. This species comes from the family Achanturidae and Siganidae. Both families dominated all substrates in each observation period. On the coral reefs of Nymph Island and Turtle Group, GBR, fish from the family Achanturidae were the most important herbivores (Hoey & Bellwood, 2007), while the family Siganidae were reported to be important herbivorous fish on coral reefs in Pioneer Bay, Orpheus Island (Fox & Bellwood, 2008).

3. The Role of Herbivorous Reef Fish in Controlling Algal Cover

Herbivorous reef fish have a very important role in the stability of the ecosystem on coral reefs. One of its roles is to control the development of algae on hard substrates through a grazing mechanism so that it opens or provides a clean space for associated biota, including corals to attach or colonize. The role of herbivorous fish, in this case, their abundance on algal development, can be studied by observing the value of algal cover in each transplanted substrate every month and associated with the abundance of herbivorous reef fish, as shown in Figure 6.

In general, it shows a pattern of decreasing algal cover value with increasing herbivorous reef fish abundance or conversely increasing algal cover value when herbivorous fish abundance decreases. This pattern is visible in the control area (rubble and natural coral) and the massive substrate. The pattern in Figure 6 indicated that the association was confirmed by simple regression analysis of the relationship between the abundance of herbivorous reef fish as the X-Axis and the value of algal cover as the Y Source (Figure 7).

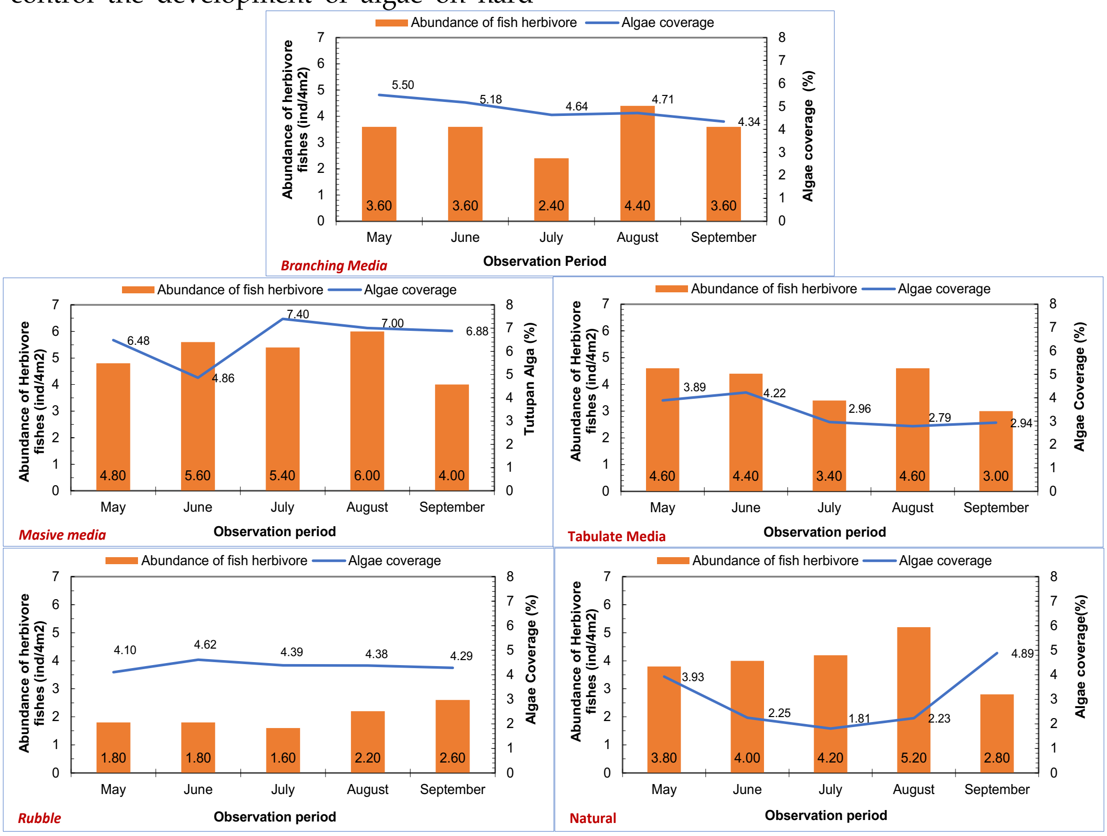

Figure 6. The dynamics of changes in algal cover and abundance of herbivorous reef fish on each use of dead coral substrate as a medium for attachment of coral fragments in transplantation activities for 5 months of observation

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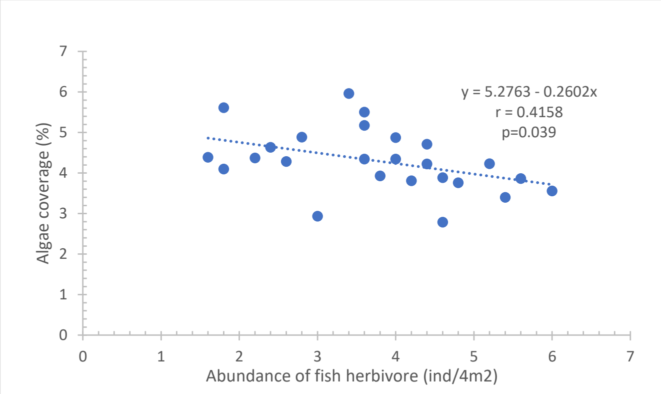

Figure 7. Scatter diagram of the relationship between herbivorous reef fish abundance and algal cover on various uses of the dead coral substrate as a medium for attachment of coral fragments for transplantation activities.

The results of the regression analysis give the equation y: 5.2763 - 0.260x with a correlation value of 0.4158. The regression equation proves that there is a linear relationship between the abundance of herbivorous fish and algal cover with a strength value of 41.58% and the relationship is negative. In the sense that an increase in the abundance of herbivorous reef fish will reduce the value of algal cover. Each increase in herbivorous fish by 1 individual will reduce algal cover by 0.26% in the transplant area. This relationship is significantly correlated based on the results of the analysis of variance with a probability value of 0.039 ($p < 0.05$).

The results of this study indicate that herbivorous fish is one of the factors that can control the high macroalgae cover in coral reef waters. Any reduction in herbivorous fish in sufficient nutrient conditions will cause an increase in macroalgae cover in the waters. This is in line with McCook's (1996) research that the presence of herbivorous fish can be a savior of certain corals from macroalgae aggression. In the Great Barrier Reef, with the experiment, the macroalga *Sargassum siliquosum* transplanted on the reef flat did not grow well if it was confined to herbivorous fish. This study proves that the high abundance of herbivorous fish is a limiting factor in the distribution of these macroalgae. Another study in Jamaica found that by limiting the fishing of herbivores in the period 1996 – 1999, the result could reduce the percentage of macroalgae cover from 60% to 10%. In eutrophic water conditions, the role of herbivorous fish is very important in maintaining corals in competition with macroalgae (Williams et al., 2001).

High macroalgae growth can be controlled by the presence of herbivorous fish (Hay, 1997). Herbivorous fish are the only mechanism controlling the growth of macroalgae in coral reefs. If the growth of macroalgae is not controlled, it will automatically dominate coral reefs (McCook, 2001). In high nutrient conditions, macroalgae growth develops rapidly so that it can cause a phase shift condition (macroalgae dominance over corals). In the end, corals lost in fighting for space and light, causing a decrease in metabolism and coral growth, but with the control of herbivorous fish, macroalgae growth conditions could be suppressed (McCook, 1996; Littler & Littlers, 1984; 2006).

Without the presence of herbivorous fish, the recovery of coral communities will be hampered by the dominance of macroalgae that quickly occupy the space left by the corals. The high role of herbivorous fish in coral reef ecosystems causes the need for restrictions on herbivorous fishing. Overexploitation will cause high algal growth (Hughes et al., 1987; Koop et al., 2001) and will eventually cause the percentage of coral cover to decrease and the mortality of young corals to increase. In addition, the abundance of herbivorous fish was positively correlated with the addition of young coral colonies through the recruitment process (Mumby et al., 2006).

Conclusion

The proportion of herbivorous fish species in the transplant area ranged from 15.81 to 58.67% and varied both based on the month of observation and the use of dead coral substrate as attachment media. The dynamics of the number of species and abundance of herbivorous reef fish had the same dynamic pattern in all dead coral substrates but varied temporally according to the time of observation. The relationship between algal cover and herbivorous reef fish abundance showed a negative and significant relationship which confirmed that the presence of herbivorous reef fish could control or reduce the value of algal cover.

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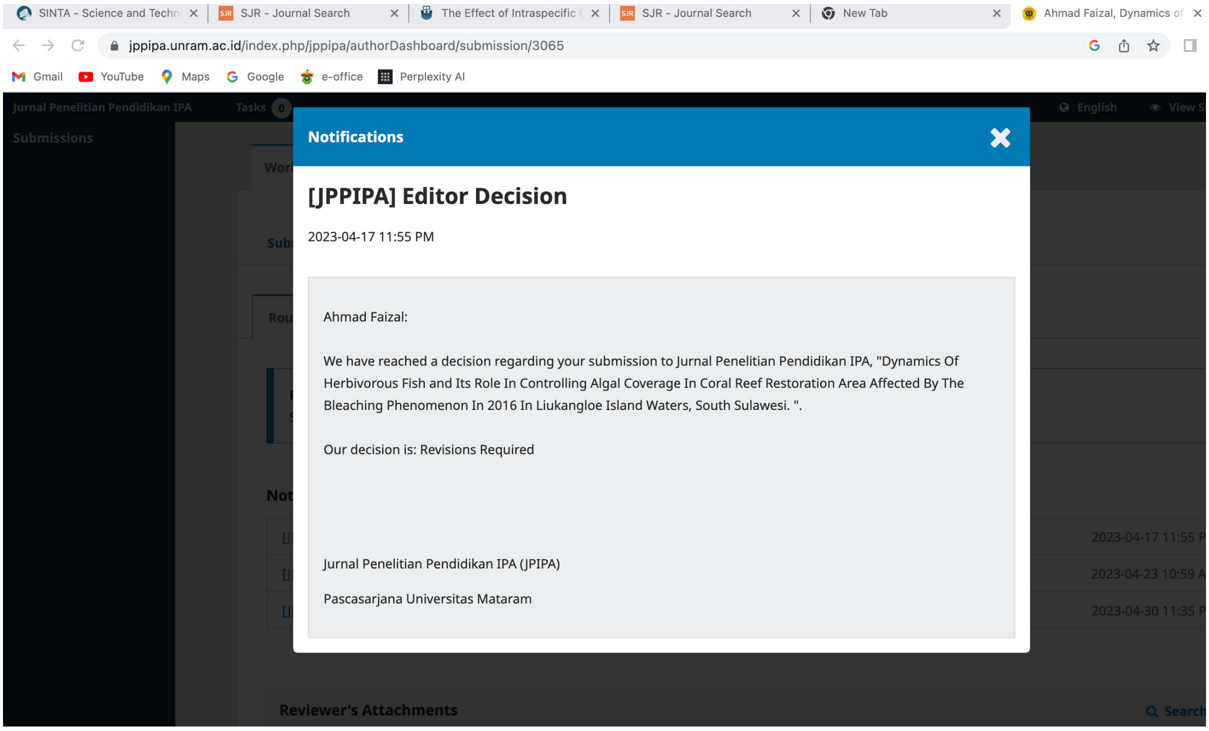
BUKTI KORESPONDESI

1. Saran Perbaikan Artikel



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Dynamics of Herbivorous Fish and Its Role in Controlling Algal Coverage in Coral Reef Restoration Area Affected by The Bleaching Phenomenon in 2016 In Liukangloe Island Waters, South Sulawesi.

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Abstract: Coral reefs in the waters of Liukangloe Island were reported to have experienced a bleaching phenomenon in May 2016 and rehabilitation efforts were carried out in 2019. This study aimed to analyze the structure of the herbivorous fish community and its role in controlling algal cover in the rehabilitation area. Observations of herbivorous fish were carried out using visual census techniques on an area of 4m² and observation of algae in 0.5x0.5 m² transects on several coral attachment media from dead coral substrates. The results showed that the proportion of herbivorous fish species in the transplant area ranged from 15.81 – 58.67% and the proportion of individuals ranged from 12.51 – 34.62%. The dynamics of the number of species and abundance of herbivorous reef fish did not show significant differences between substrates and had the same dynamic pattern in all substrate uses, but varied temporally according to the time of observation. The exception is the rubble area which continues to increase until the end of the observation. A high number of herbivorous fish species richness was observed in the branching and natural coral substrates and low in the rubble substrate. The abundance of herbivorous reef fish showed a significant and negative relationship to algal cover and confirmed that the presence of herbivorous reef fish could control or reduce the value of algal cover.

Keywords: Coral reefs, herbivorous fish, algae, Liukangloe Island.

Citation:

Introduction

The coral bleaching incident in May 2016 on the coral reefs of Liukangloe Island caused coral bleaching of> 50% and caused coral reef damage of> 40% (Nirwan, et al., 2017). The results of monitoring the impact of bleaching in 2017 found that at a depth of 3-5m, the impact of bleaching was high and occurred at all observation points with coral mortality of 35-60% (Rani et al., 2017). The event of coral bleaching has caused coral death and changed the basic structure of coral reefs. These changes will have an impact on associated biota, including a decrease in the wealth and abundance of reef fish, and can trigger macroalgae growth due to the availability of substrate in the form of dead coral. In addition, the decline in the population of herbivorous animals, including herbivorous fish, is also the cause of the increased abundance of algae and the increasing space competition between algae and corals (Glynn, 1993; Jompa & McCook, 2002; Ateweberhan et al., 2013 Couch et al., 2017)

Reef fish whose lives are related to coral reefs, the damage or decline in the condition of coral reefs naturally affects the diversity and abundance of reef fish. According to Ampou et al., (2017), disturbances that

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occur on coral reefs over a longer period (annual) may lead to lower fish abundance and diversity.

The interaction between algae and coral is one part of the ecological process. Algae as primary producers become one of the energy contributors for most herbivorous animals on coral reefs. However, algae are also major competitors for space with corals and may change the balance of coral reefs when their presence predominates. Algae growth is classified as very fast so it can be used as an indicator that affects populations and communities of various coral reef biota (Maududi & Luthfi, 2018).

In relation to algae in coral reef ecosystems, herbivorous fish are the main factors influencing changes in algal communities (Faizal *et al*., 2012). Herbivorous fish are the main controlling component of macroalgae growth with a functional role as direct consumers eg., grazers, macroalgae herbivores, scrapers target different type of algae and have differential impact on the algae growth control (Pombo-Ayora et. al., 2020). The grazing activity of herbivorous fish is very important in creating open spaces for corals to settle and increasing coral recruitment by reducing algal cover (Bridge *et al*., 2013; Davies, 2013; Frimanozi *et al*., 2019). In addition, Husain *et al*. (2013) stated that the composition of herbivorous reef fish can control the presence of algae distribution in coral reef resilience.

Concerning the bleaching phenomenon in 2016 on the coral reefs of Liukangloe Island, in 2019, research was carried out on coral reef restoration techniques through the use of various dead coral substrate media that were still intact by bleaching events as attachment media for coral transplantation. This study proved that the use of branching, massive, and tabulated dead coral media was equally effective in supporting the growth of transplanted corals and did not show differences in growth from natural corals as controls for several coral species tested (Rani et al., 2020). Therefore, it is necessary to study the dynamics of the herbivorous reef fish community structure and its role in controlling algae cover in coral reef rehabilitation areas.

Method

1. Study Area

This research was conducted in the coral reef rehabilitation area that experienced bleaching in 2016 on the coral reefs of Liukangloe Island, Bulukumba Regency. The research was carried out for 5 months, from May to September 2021. In this study, 2 research stations were set on the north and east sides of the island. The main consideration is the number of bleaching events at that location. At Station 1, there are three deployment areas, while Stations 2 and 3 have only one deployment area each (a total of 5 deployment areas). In each placement area, there are three observation points according to the substrate media used in coral transplantation activities.

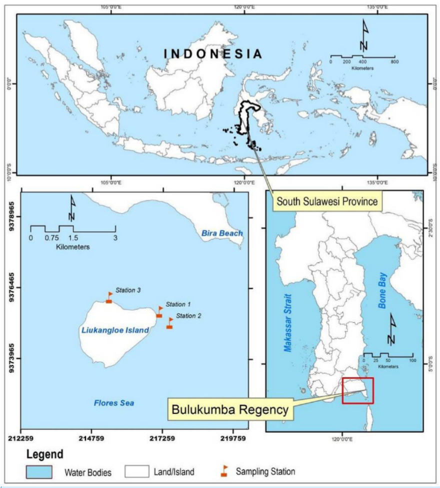

Figure 1. Map of sampling sites in the waters off the west coast of South Sulawesi

2. Media of Coral Transplant

Restoration of coral reefs with transplantation techniques is carried out by the attachment method using natural substrates in the form of dead coral that is still intact. Infrequently dead substrate media used were in the form of branching, massive, and tabulated substrates. As for the technical use of dead coral substrate as attachment media, namely 1) Branching coral substrate: Transplant coral fragments are tied to the branch ends of the natural substrate using cable ties; 2) Massive coral substrate: The transplanted coral fragments are attached to nails using a plastic cable (cable tie) before the nails are attached to the dead coral skeleton substrate; and 3) Tabulate coral substrate: selected colonies with large branching structures and still intact. The transplanted coral fragments were tied to the large branches using cable ties (Figure 2).

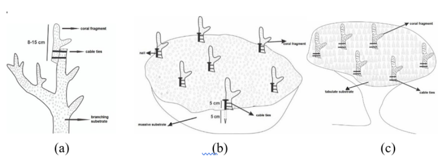

Figure 2. The dead coral substrate is used as an attachment medium for transplanted coral fragments in transplantation activities (a: branching coral; b: massive coral; and c: tabulate coral.

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Substrate treatment for attachment media was repeated 5 times in 5 treatment areas in an area of 4 m2 at a depth of 3 - 5 m. In each of these techniques, 10 coral fragments were transplanted per test coral species (*Acropora nobilis, Acropora formosa,* and *Porites cylindrica*) or 30 fragments per experimental unit. Placement points for the attachment of 30 fragments for all types of test corals were carried out randomly with a spacing of 20 cm. The transplanted coral fragments were measured for changes in branch length using calipers every month for 5 months of the study, and at the end of the study, the survival rate of each type of coral was also calculated. The results showed that the three media used showed their effectiveness in supporting the growth of transplanted coral fragments tested and were as good as natural coral growth, while success in the survival parameters, the use of dead and branching coral media gave better results than tabulate corals (Rani et al., 2020).

3. Method Samples Collection

The algal cover was observed by placing a quadrant in the transplant area in each experimental unit using the dead coral substrate. The observation point is marked in the form of a float to facilitate the placement of the quadrant during subsequent observations. The assessment of the percentage of algal cover used a method that was modified by Faizal (2011; 2012). The quadrant used is 05 x 0.5 m2 with a lattice of 10 x 10 cm2. The cover unit category for each lattice is used on a scale of ¼, ½, ¾, and 1 unit. The area of algal cover in the quadrant grid was recorded in unit cover values and pictures were taken.

Observations of reef fish in each experimental unit were carried out using the stationary visual census technique, i.e., the reef fish present in the area (2m x 2m = $4m^2$) were recorded for the species and the number of individuals by staying silent in the center of the observation area. Identification of reef fish was carried out following the instructions of Allen (2000) and Kuiter & Tonozuka (2001).

Observations of coral reef fish and algae cover were also carried out in non-transplanted areas as a control on damaged coral reef areas, dominated by rubble and natural coral areas. The observation area is the same as the observation area in the transplanted area (4 m^2) and it is also repeated 5 times.

4. Data analysis

Assessment of herbivorous reef fish community structure, i.e., the proportion of herbivorous fish to the total number of reef fish (number of species and number of individuals) in each treatment using substrate and control areas were analyzed descriptively with the help of graphs. The monthly dynamics of algae and herbivorous fish were also analyzed descriptively with the help of line graphs.

Differences in species richness and abundance of herbivorous fish between the use of dead coral substrates (including controls in the form of rubble-based substrates and natural coral) were analyzed using analysis of variance (one-way ANOVA), the number of replicates of each substrate was 5 times. Analysis of variance was carried out for each month of observation (May to September 2021). The results of the analysis are presented in graphical form. The analysis of the role of herbivorous reef fish in controlling algae cover was carried out by plotting the abundance of herbivorous reef fish with algae cover values in a scatter graph, while the relationship between algae cover and herbivorous fish abundance was analyzed by regression analysis.

Result and Discussion

The dynamics of changes in the community structure of herbivorous reef fish and their role in controlling algae cover during the 5 months of observation showed monthly variations in each experimental unit in the use of dead coral substrate as attachment media and also in control areas.

1. Herbivorous Fish Community Structure

The proportions of the presence of herbivorous reef fish in each treatment medium during the 5 months of observation are presented in Figures 3 and 4.

The proportion of herbivorous fish based on the number of reef fish species varied between dead coral substrates as transplantation media and also varied according to the month of observation. The magnitude of the variation ranges from 15.81 to 58.67% and depends on the substrate media used. The low proportion of herbivorous fish was found in natural coral (15.81 – 26.93%) and the highest in the control area in the form of rubble substrate (30 -58.67%) and branching substrate (25.6 – 53.67%). As for the massive substrate, it is relatively the same as the tabulated substrate.

Monthly dynamics of the proportion of the number of herbivorous species in each substrate and control fluctuated in a low value or could be said to be stable, except in rubble and branching areas with high dynamics. In the rubble area, it continued to increase with a high percentage in July until the end of the observation, and in the branching substrate which increased rapidly in August after experiencing a decrease in July.

The results showed that the high proportion of herbivorous fish species in the rubble area was caused by the availability of algae or macroalgae at the bottom of the waters. According to Burkepile & Hay (2011), the abundance of herbivorous reef fish is related to food and water conditions. Herbivorous reef fish are generally predators of benthic algae, so their distribution is

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Commented [HC14]: delete nomor, format italic determined by the presence of groups of benthic algae. The results of the research by Wibowo et al. (2016) showed that the number of species and abundance of herbivorous reef fish were positively correlated with the number of genera and density of young coral colonies recruited as a result of the grazing process of herbivorous reef fish.

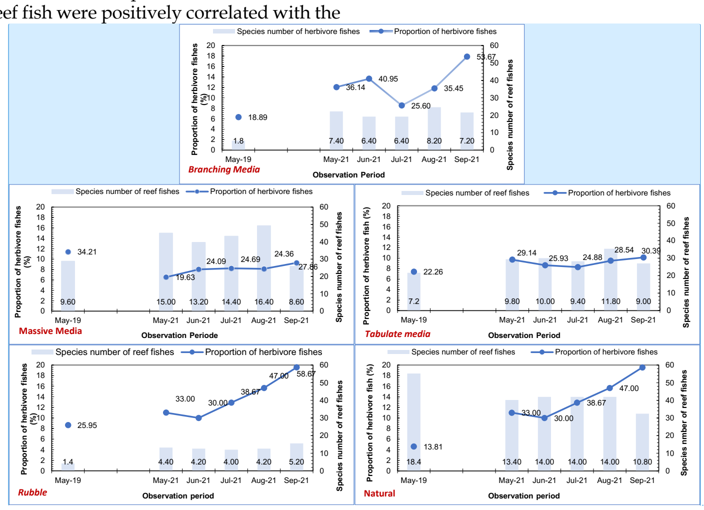

Figure 3. The dynamics of the proportion of the number of herbivorous reef fish species to the number of reef fish species on various transplant media for 5 months of observation.

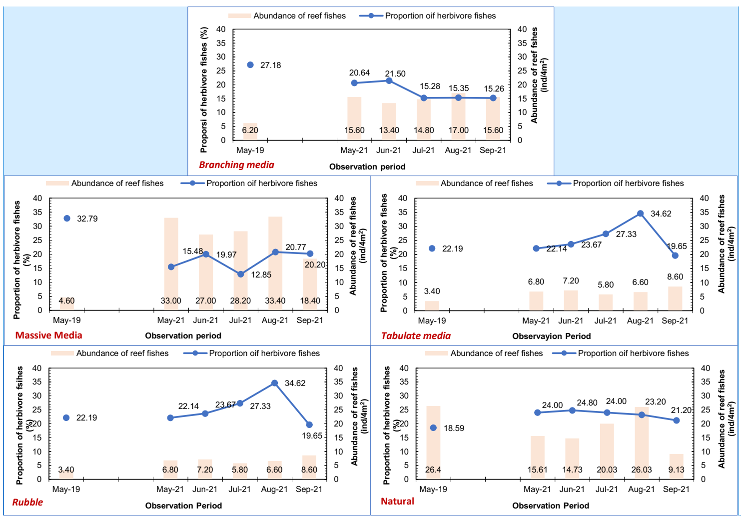

Figure 4. The dynamics of the proportion of individual herbivorous reef fish to the number of individual reef fish on various transplant media for 5 months of observation

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Based on the number of individuals, the proportion of herbivorous fish ranged from 12.51 to 34.62%. A high proportion of herbivorous fish individuals was observed in the control area, namely on rubble and natural coral substrates. While the low in the other 3 substrates (branching, massive, and tabulate) ranged from 12 – 20% (Figure 4). Monthly dynamics, experience small fluctuations or can be said to be stable throughout the observations. The exception for the control substrate was rubble, which experienced a fairly large increase in August, but decreased again as in the early observations.

The number of individuals and the proportion of herbivorous fish in the waters of Liukang Loe tends to be stable, this may be due to water conditions and water quality which tend to be uniform. According to Rani et al., (2017), under the same conditions of water quality and environment, the number of individual herbivorous fish may also be the same. Husain (2012) research, shows that the better the brightness, the more abundance of herbivorous reef fish will be. This is due to the influence of topography and depth which provides healthier ecological conditions.

Although it tends to be stable on each type of substrate, the presence of this herbivorous fish also shows a different proportion in each type of substrate. This difference is caused by the abundance of herbivorous reef fish related to food and water conditions. Herbivorous reef fish are generally predators of benthic algae, so their distribution is related to the presence of certain groups of algae. For example, the abundance of the scrapers group will be different from that of the browser's group which indicates a difference in the distribution of the algae group consumed or preferred (Burkepile & Hay, 2011). Figure 4 also shows that there is a change in the number of individuals from each observation point from time to time. This change is also one of the bioindicators of coral ecosystem health (Cole et al., 2008; Obura & Grimsdith, 2009). Herbivorous fish are the indicator fish to control the growth of algae that can inhibit the recruitment of new corals (Green & Bellwood, 2009; Obura & Grimsdith, 2009).

2. Diversity and Abundance of Coral Fish

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The diversity and abundance of herbivorous reef fish are one of the main components and play an important role in coral reef ecology. Its existence is very dynamic in space and time and is closely related to the dynamics of algae cover as its main food. The results of observations on various transplant media using dead coral substrate during the 5 months of observation and at the beginning of the study are presented in Figure 5.

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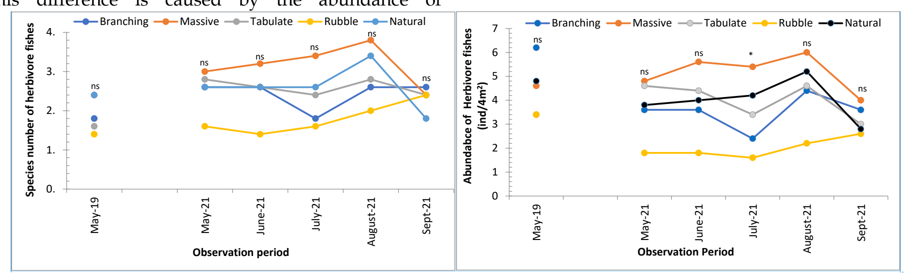

Figure 5. The dynamics of species richness (a) and abundance of herbivorous reef fish (b) on various dead coral substrates as attachment media in coral transplantation for 5 months of observation. ns: not significantly different

The spatial and temporal dynamics of the number and abundance of herbivorous reef fish have dynamics that vary greatly in temporal terms. Species richness and abundance of herbivorous reef fish had the same pattern of change in all substrates, including controls. It decreased in July and increased rapidly in August and then declined again in September (Figure 5 and Table 2). The exception is the rubble area which continues to increase until the end of the observation.

High herbivorous fish species richness was observed in branching and natural coral substrates and low in rubble substrates. Acanthuridae is a family of herbivorous fish that has the greatest number of species found (7 species) and for families Scaridae and Siganidae there are only 2 species each (Table 1 and Table 2).

Table 1. Distribution of individual herbivorous reef fish on various dead coral substrates for attachment media for transplanted coral fragments

Family	Species	Coral dead substrates				
		Branching	Massive	Tabulate	Rubble	Natural
Achanturidae	*Acanthurus leucosternon*	1	0	0	0	0
	A. lineatus	1	0	1	0	0
	A.pyropherus	3	0	0	0	1
	A.nigricans	12	32	12	8	17
	Naso lituratus	2	2	0	0	1
	Ctenochaetus striatus	26	37	39	22	24
	Zebrasoma scopas	26	33	30	6	27
Scaridae	*Chlorurus microrhinos*	0	6	0	0	2
	Scarus sp	3	12	0	8	7
Siganidae	*Siganus virgatus*	9	4	7	2	5
	Siganus vulpinus	5	3	11	4	16
	Total	**88**	**129**	**100**	**50**	**100**

Table 2. Distribution of herbivorous reef fish individuals by month of observation in the transplant area

Family	Species	Observation Period				
		May	June	July	August	September
Achanturidae	*Acanthurus leucosternon*	1				
	A. lineatus	1	1			
	A.pyropherus	2			1	1
	A.nigricans	18	15	17	20	11
	Naso lituratus				1	4
	Ctenochaetus striatus	33	27	29	35	24
	Zebrasoma scopas	24	31	25	30	12
Scaridae	*Chlorurus microrhinos*	1	1	1	1	4
	Scarus sp	5	7	4	8	6
Siganidae	*Siganus virgatus*	2	4	4	7	10
	Siganus vulpinus	6	11	5	9	8
	Total	**93**	**97**	**85**	**112**	**80**

Based on the abundance of herbivorous fish, massive substrate, tabulate, and natural coral had the highest abundance, and the lowest was found in the rubble area (Figure 5 and Table 1). The herbivorous fish species with the most common distribution based on the coral substrate and the month of observation were *Acanthurus nigricans, Ctenochaetus striatus*, and *Sebrasoma scopas*. However, the results of the analysis of variance showed that the number of species and abundance of herbivorous reef fish between dead coral substrates (including control in the form of rubble and natural coral) in each month of observation did not show a significant difference (p> 0.05), except for observations in July, it was found that there was a difference in the abundance of herbivorous fish (p<0.05). No significant differences in the number of species and abundance of herbivorous reef fish were also observed at the start of the study (before transplant, in May 2019). The results of the analysis of variance for the number of species and abundance of herbivorous reef fish are presented in Table 3 and Table 4.

Table 3. Results of the analysis of variance on the species richness of herbivorous reef fish between substrate use in each observation period

Obervation Period	Source of Variation	Sum of Squares	df	Mean Square	F	Sig.
May 2019	Between Groups	4.24	4	1.06	1.83	0.16
	Within Groups	11.6	20	0.58		
	Total	15.84	24			
May 2021	Between Groups	5.84	4	1.46	1.30	0.30
	Within Groups	22.4	20	1.12		
	Total	28.24	24			
June 2021	Between Groups	8.64	4	2.16	1.29	0.31
	Within Groups	33.6	20	1.68		
	Total	42.24	24			
July 2021	Between Groups	10.16	4	2.54	1.84	0.16
	Within Groups	27.6	20	1.38		
	Total	37.76	24			
August 2021	Between Groups	9.84	4	2.46	2.46	0.08
	Within Groups	20	20	1		
	Total	29.84	24			
September 2021	Between Groups	1.84	4	0.46	0.43	0.79
	Within Groups	21.6	20	1.08		
	Total	23.44	24			

Table 4. The results of the analysis of variance on the abundance of herbivorous reef fish between substrate uses in each observation period

Obervation Period	Source of Variation	Sum of Squares	df	Mean Square	F	Sig.
May 2019	Between Groups	27.04	4	6.76	1.59	0.22
	Within Groups	85.2	20	4.26		
	Total	112.24	24			
May 2021	Between Groups	28.24	4	7.06	2.11	0.12
	Within Groups	66.8	20	3.34		
	Total	95.04	24			
June 2021	Between Groups	38.24	4	9.56	1.90	0.15
	Within Groups	100.4	20	5.02		
	Total	138.64	24			
July 2021	Between Groups	44.4	4	11.1	3.49	0.03
	Within Groups	63.6	20	3.18		
	Total	108	24			
August 2021	Between Groups	40.24	4	10.06	2.29	0.10
	Within Groups	88	20	4.4		
	Total	128.24	24			
September 2021	Between Groups	6.8	4	1.7	0.51	0.73
	Within Groups	67.2	20	3.36		
	Total	74	24			

The distribution of herbivorous reef fish both based on the substrate and the month of observation as shown in Table 1 and Table 2, shows that the families Achanturidae and Siganidae were found in each type of substrate. The Siganidae family is a family of herbivorous reef fish that are selective in choosing their food and usually live in shallow waters (Sale, 1991). This family prefers macroalgae that have wide sheets like turf algae so that the fish can tear them easily. Turf algae are the dominant macroalgae group in coral reef ecosystems (Sale, 1991; Jompa & McCook, 2003).

During the observation period, herbivorous fish species from the families Acanthuridae (surgeonfish), Scaridae (parrotfish), and Siganidae (rabbitfish) were found in various transplanted substrates. The results of this study confirm various similar studies in tropical waters (Tomascik et al., 1997). For example, similar cases were reported from San Blas Islands Panama, and Ambergris Caye, Belize with Kyposiadae composition having the same proportions as Acanthuridae, Scaridae, and Siganidae (William et al., 2001). Similarly, reports from subtropical waters such as the Great Barrier Reef

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(Russ, 1984) in the waters of Lizard Island with a composition of herbivorous fish abundance for Acanthuridae 54%, Scaridae 31%, and Siganidae (14%) (Meekan & Choat, 1997).

The highest herbivorous reef fish species found on various substrates during the study were *Ctenochaetus striatus*, *Zebrasoma scopas* and *Siganus vulpinus*. This species comes from the family Achanturidae and Siganidae. Both families dominated all substrates in each observation period. On the coral reefs of Nymph Island and Turtle Group, GBR, fish from the family Achanturidae were the most important herbivores (Hoey & Bellwood, 2007), while the family Siganidae were reported to be important herbivorous fish on coral reefs in Pioneer Bay, Orpheus Island (Fox & Bellwood, 2008).

3. The Role of Herbivorous Reef Fish in Controlling Algal Cover

Herbivorous reef fish have a very important role in the stability of the ecosystem on coral reefs. One of its roles is to control the development of algae on hard substrates through a grazing mechanism so that it opens or provides a clean space for associated biota, including corals to attach or colonize. The role of herbivorous fish, in this case, their abundance on algal development, can be studied by observing the value of algal cover in each transplanted substrate every month and associated with the abundance of herbivorous reef fish, as shown in Figure 6.

In general, it shows a pattern of decreasing algal cover value with increasing herbivorous reef fish abundance or conversely increasing algal cover value when herbivorous fish abundance decreases. This pattern is visible in the control area (rubble and natural coral) and the massive substrate. The pattern in Figure 6 indicated that the association was confirmed by simple regression analysis of the relationship between the abundance of herbivorous reef fish as the X-Axis and the value of algal cover as the Y Source (Figure 7).

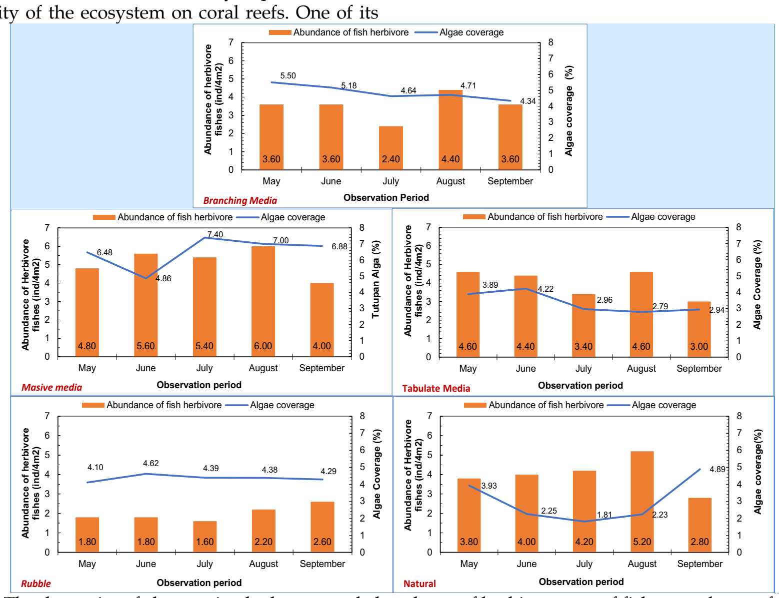

Figure 6. The dynamics of changes in algal cover and abundance of herbivorous reef fish on each use of dead coral substrate as a medium for attachment of coral fragments in transplantation activities for 5 months of observation

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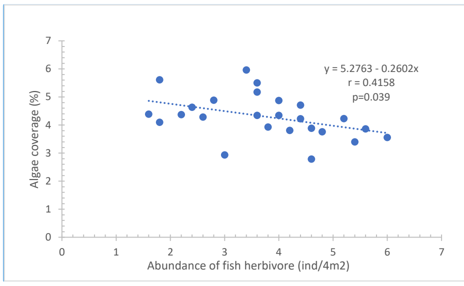

Figure 7. Scatter diagram of the relationship between herbivorous reef fish abundance and algal cover on various uses of the dead coral substrate as a medium for attachment of coral fragments for transplantation activities.

The results of the regression analysis give the equation y: 5.2763 - 0.260x with a correlation value of 0.4158. The regression equation proves that there is a linear relationship between the abundance of herbivorous fish and algal cover with a strength value of 41.58% and the relationship is negative. In the sense that an increase in the abundance of herbivorous reef fish will reduce the value of algal cover. Each increase in herbivorous fish by 1 individual will reduce algal cover by 0.26% in the transplant area. This relationship is significantly correlated based on the results of the analysis of variance with a probability value of 0.039 ($p < 0.05$).

The results of this study indicate that herbivorous fish is one of the factors that can control the high macroalgae cover in coral reef waters. Any reduction in herbivorous fish in sufficient nutrient conditions will cause an increase in macroalgae cover in the waters. This is in line with McCook's (1996) research that the presence of herbivorous fish can be a savior of certain corals from macroalgae aggression. In the Great Barrier Reef, with the experiment, the macroalga *Sargassum siliquosum* transplanted on the reef flat did not grow well if it was confined to herbivorous fish. This study proves that the high abundance of herbivorous fish is a limiting factor in the distribution of these macroalgae. Another study in Jamaica found that by limiting the fishing of herbivores in the period 1996 – 1999, the result could reduce the percentage of macroalgae cover from 60% to 10%. In eutrophic water conditions, the role of herbivorous fish is very important in maintaining corals in competition with macroalgae (Williams et al., 2001).

High macroalgae growth can be controlled by the presence of herbivorous fish (Hay, 1997). Herbivorous fish are the only mechanism controlling the growth of macroalgae in coral reefs. If the growth of macroalgae is not controlled, it will automatically dominate coral reefs (McCook, 2001). In high nutrient conditions, macroalgae growth develops rapidly so that it can cause a phase shift condition (macroalgae dominance over corals). In the end, corals lost in fighting for space and light, causing a decrease in metabolism and coral growth, but with the control of herbivorous fish, macroalgae growth conditions could be suppressed (McCook, 1996; Littler & Littlers, 1984; 2006).

Without the presence of herbivorous fish, the recovery of coral communities will be hampered by the dominance of macroalgae that quickly occupy the space left by the corals. The high role of herbivorous fish in coral reef ecosystems causes the need for restrictions on herbivorous fishing. Overexploitation will cause high algal growth (Hughes et al., 1987; Koop et al., 2001) and will eventually cause the percentage of coral cover to decrease and the mortality of young corals to increase. In addition, the abundance of herbivorous fish was positively correlated with the addition of young coral colonies through the recruitment process (Mumby et al., 2006).

Conclusion

The proportion of herbivorous fish species in the transplant area ranged from 15.81 to 58.67% and varied both based on the month of observation and the use of dead coral substrate as attachment media. The dynamics of the number of species and abundance of herbivorous reef fish had the same dynamic pattern in all dead coral substrates but varied temporally according to the time of observation. The relationship between algal cover and herbivorous reef fish abundance showed a negative and significant relationship which confirmed that the presence of herbivorous reef fish could control or reduce the value of algal cover.

Acknowledgements

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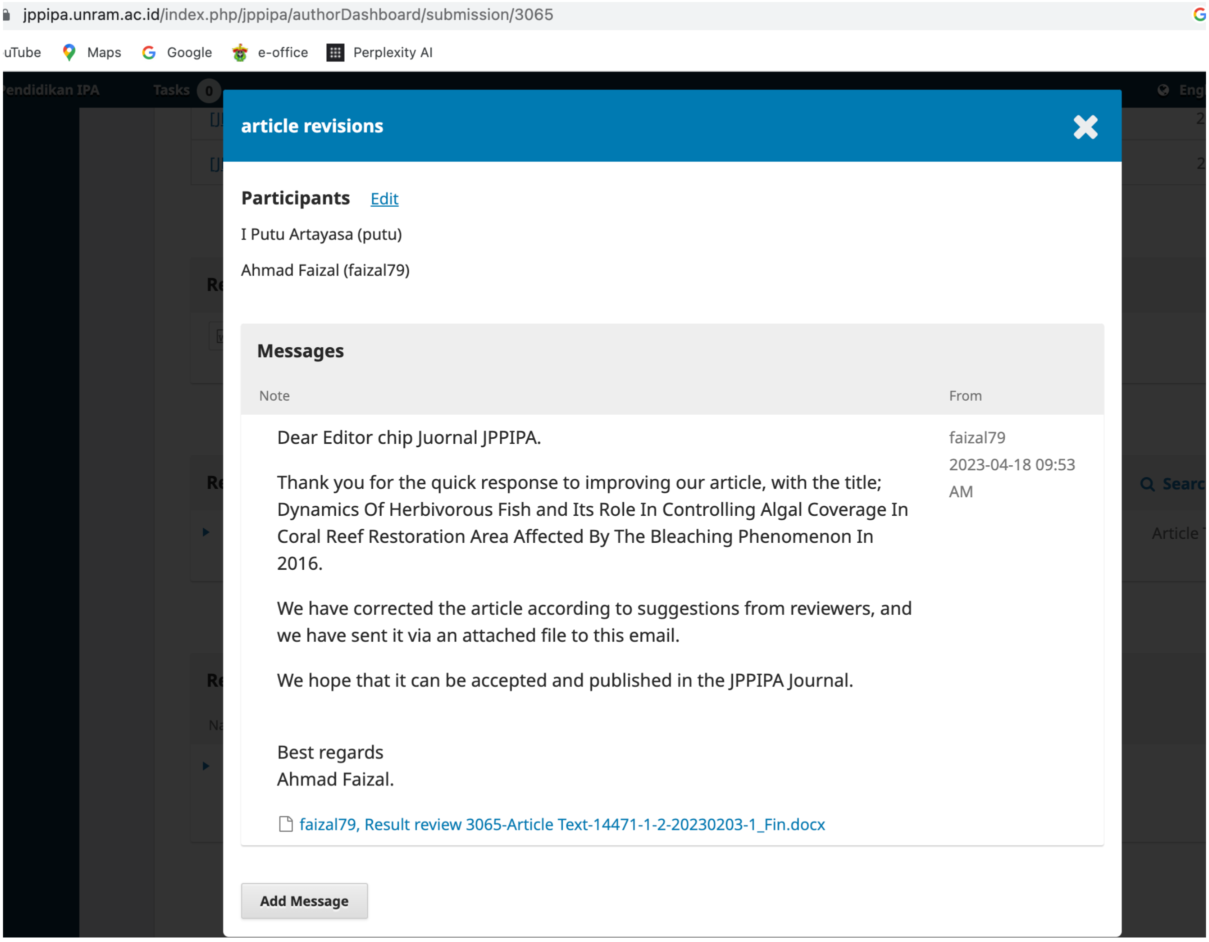

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Dynamics of Herbivorous Fish and Its Role in Controlling Algal Coverage in Coral Reef Restoration Area Affected by The Bleaching Phenomenon in 2016

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Abstract: Coral reefs in the waters of Liukangloe Island were reported to have experienced a bleaching phenomenon in May 2016 and rehabilitation efforts were carried out in 2019. This study aimed to analyze the structure of the herbivorous fish community and its role in controlling algal cover in the rehabilitation area. Observations of herbivorous fish were carried out using visual census techniques on an area of 4m² and observation of algae in 0.5x0.5 m² transects on several coral attachment media from dead coral substrates. The results showed that the proportion of herbivorous fish species in the transplant area ranged from 15.81 – 58.67% and the proportion of individuals ranged from 12.51 – 34.62%. The dynamics of the number of species and abundance of herbivorous reef fish did not show significant differences between substrates and had the same dynamic pattern in all substrates uses but varied temporally according to the time of observation. The exception is the rubble area which continues to increase until the end of the observation. A high number of herbivorous fish species richness was observed in the branching and natural coral substrates and low in the rubble substrate. The abundance of herbivorous reef fish showed a significant and negative relationship to algal cover and confirmed that the presence of herbivorous reef fish could control or reduce the value of algal cover.

Keywords: Algae; Coral reefs; Herbivorous Fish; Liukangloe Island.

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Introduction

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The coral bleaching incident in May 2016 on the coral reefs of Liukangloe Island caused coral bleaching of> 50% and caused coral reef damage of> 40% (Nirwan et al., 2017). The results of monitoring the impact of bleaching in 2017 found that at a depth of 3-5m, the impact of bleaching was high and occurred at all observation points with coral mortality of 35-60%(Rani et al., 2020). The event of coral bleaching has caused coral death and changed the basic structure of coral reefs. These changes will have an impact on associated biota, including a decrease in the wealth and abundance of reef fish, and can trigger macroalgae growth due to the availability of substrate in the form of dead coral. In addition, the decline in the population of herbivorous animals, including herbivorous fish, is also the cause of the increased abundance of algae and the increasing space competition between algae and corals (Couch et al., 2017; Ateweberhan et al., 2013; Cure et al., 2021; Tebbett et al., 2023)

Reef fish whose lives are related to coral reefs, the damage or decline in the condition of coral reefs naturally affects the diversity and abundance of reef fish.

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According to Elvan Ampou et al., (2017), disturbances that occur on coral reefs over a longer period (annual) may lead to lower fish abundance and diversity.

The interaction between algae and coral is one part of the ecological process. Algae as primary producers become one of the energy contributors for most herbivorous animals on coral reefs. However, algae are also major competitors for space with corals and may change the balance of coral reefs when their presence predominates. Algae growth is classified as very fast so it can be used as an indicator that affects populations and communities of various coral reef biota (Maududi & Luthfi, 2018).

In relation to algae in coral reef ecosystems, herbivorous fish are the main factors influencing changes in algal communities (Faizal et al., 2012). Herbivorous fish are the main controlling component of macroalgae growth with a functional role as direct consumers eg., grazers, macroalgae herbivores, scrapers target different type of algae and have differential impact on the algae growth control (Pombo-Ayora et al., 2020). The grazing activity of herbivorous fish is very important in creating open spaces for corals to settle and increasing coral recruitment by reducing algal cover (Bridge et al., 2013; Davies et al., 2013; Frimanozi et al., 2019). In addition, Elma et al., (2023) stated that the composition of herbivorous reef fish can control the presence of algae distribution in coral reef resilience.

Concerning the bleaching phenomenon in 2016 on the coral reefs of Liukangloe Island, in 2019, research was carried out on coral reef restoration techniques through the use of various dead coral substrate media that were still intact by bleaching events as attachment media for coral transplantation. This study proved that the use of branching, massive, and tabulated dead coral media was equally effective in supporting the growth of transplanted corals and did not show differences in growth from natural corals as controls for several coral species tested (Rani et al., 2020). Therefore, it is necessary to study the dynamics of the herbivorous reef fish community structure and its role in controlling algae cover in coral reef rehabilitation areas.

Method

Study Area

This research was conducted in the coral reef rehabilitation area that experienced bleaching in 2016 on the coral reefs of Liukangloe Island, Bulukumba Regency. The research was carried out for 5 months, from May to September 2021. In this study, 2 research stations were set on the north and east sides of the island. The main consideration is the number of bleaching events at that location. At Station 1, there are three deployment areas, while Stations 2 and 3 have only one deployment area each (a total of 5 deployment areas). In each placement area, there are three observation points according to the substrate media used in coral transplantation activities.

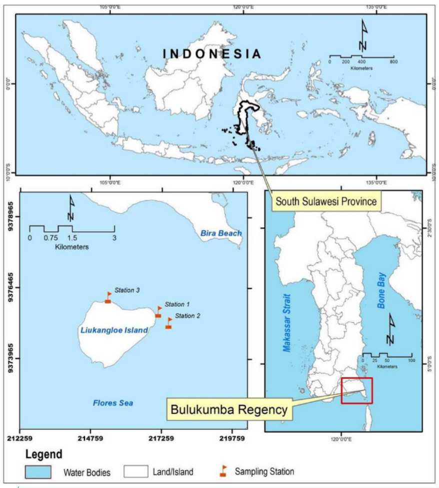
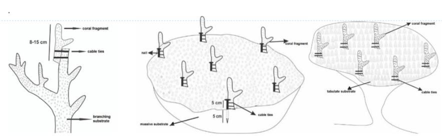


Figure 1. Map of sampling sites in the waters off the west coast of South Sulawesi

Media of Coral Transplant

Restoration of coral reefs with transplantation techniques is carried out by the attachment method using natural substrates in the form of dead coral that is still intact. Infrequently dead substrate media used were in the form of branching, massive, and tabulated substrates. As for the technical use of dead coral substrate as attachment media, namely 1) Branching coral substrate: Transplant coral fragments are tied to the branch ends of the natural substrate using cable ties; 2) Massive coral substrate: The transplanted coral fragments are attached to nails using a plastic cable (cable tie) before the nails are attached to the dead coral skeleton substrate; and 3) Tabulate coral substrate: selected colonies with large branching structures and still intact. The transplanted coral fragments were tied to the large branches using cable ties (Figure 2).



(a) (b) (c)

Figure 2. The dead coral substrate is used as an attachment medium for transplanted coral fragments in transplantation activities; (a) branching coral; (b) massive coral; and (c) tabulate coral.

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Substrate treatment for attachment media was repeated 5 times in 5 treatment areas in an area of 4 m2 at a depth of 3 - 5 m. In each of these techniques, 10 coral fragments were transplanted per test coral species (*Acropora nobilis, Acropora formosa,* and *Porites cylindrica*) or 30 fragments per experimental unit. Placement points for the attachment of 30 fragments for all types of test corals were carried out randomly with a spacing of 20 cm. The transplanted coral fragments were measured for changes in branch length using calipers every month for 5 months of the study, and at the end of the study, the survival rate of each type of coral was also calculated. The results showed that the three media used showed their effectiveness in supporting the growth of transplanted coral fragments tested and were as good as natural coral growth, while success in the survival parameters, the use of dead and branching coral media gave better results than tabulate corals (Rani et al., 2020).

Method Samples Collection

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The algal cover was observed by placing a quadrant in the transplant area in each experimental unit using the dead coral substrate. The observation point is marked in the form of a float to facilitate the placement of the quadrant during subsequent observations. The assessment of the percentage of algal cover used a method that was modified by Faizal et al., 2012; Fabricius et al., 2023. The quadrant used is 05 x 0.5 m2 with a lattice of 10 x 10 cm2. The cover unit category for each lattice is used on a scale of ¼, ½, ¾, and 1 unit. The area of algal cover in the quadrant grid was recorded in unit cover values and pictures were taken.

Observations of reef fish in each experimental unit were carried out using the stationary visual census technique, i.e., the reef fish present in the area (2m x 2m = 4m^2) were recorded for the species and the number of individuals by staying silent in the center of the observation area. Identification of reef fish was carried out following the instructions (Allen et al., 1999).

Observations of coral reef fish and algae cover were also carried out in non-transplanted areas as a control on damaged coral reef areas, dominated by rubble and natural coral areas. The observation area is the same as the observation area in the transplanted area (4 m^2) and it is also repeated 5 times.

Data analysis

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Assessment of herbivorous reef fish community structure, i.e., the proportion of herbivorous fish to the total number of reef fish (number of species and number of individuals) in each treatment using substrate and control areas were analyzed descriptively with the help of graphs. The monthly dynamics of algae and herbivorous fish were also analyzed descriptively with the help of line graphs.

Differences in species richness and abundance of herbivorous fish between the use of dead coral substrates (including controls in the form of rubble-based substrates and natural coral) were analyzed using analysis of variance (one-way ANOVA), the number of replicates of each substrate was 5 times. Analysis of variance was carried out for each month of observation (May to September 2021). The results of the analysis are presented in graphical form. The analysis of the role of herbivorous reef fish in controlling algae cover was carried out by plotting the abundance of herbivorous reef fish with algae cover values in a scatter graph, while the relationship between algae cover and herbivorous fish abundance was analyzed by regression analysis.

Result and Discussion

The dynamics of changes in the community structure of herbivorous reef fish and their role in controlling algae cover during the 5 months of observation showed monthly variations in each experimental unit in the use of dead coral substrate as attachment media and also in control areas.

Herbivorous Fish Community Structure

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The proportions of the presence of herbivorous reef fish in each treatment medium during the 5 months of observation are presented in Figures 3 and 4.

The proportion of herbivorous fish based on the number of reef fish species varied between dead coral substrates as transplantation media and also varied according to the month of observation. The magnitude of the variation ranges from 15.81 to 58.67% and depends on the substrate media used. The low proportion of herbivorous fish was found in natural coral (15.81 – 26.93%) and the highest in the control area in the form of rubble substrate (30 -58.67%) and branching substrate (25.6 – 53.67%). As for the massive substrate, it is relatively the same as the tabulated substrate.

Monthly dynamics of the proportion of the number of herbivorous species in each substrate and control fluctuated in a low value or could be said to be stable, except in rubble and branching areas with high dynamics. In the rubble area, it continued to increase with a high percentage in July until the end of the observation, and in the branching substrate which increased rapidly in August after experiencing a decrease in July.

The results showed that the high proportion of herbivorous fish species in the rubble area was caused by the availability of algae or macroalgae at the bottom of the waters. According to Burkepile & Hay, (2011), the abundance of herbivorous reef fish is related to food and water conditions. Herbivorous reef fish are generally predators of benthic algae, so their distribution is determined by the presence of groups of benthic algae. The results of the research by Wibowo et al., (2016) showed that the number of species and abundance of herbivorous reef fish were positively correlated with the number of genera and density of young coral colonies recruited as a result of the grazing process of herbivorous reef fish.

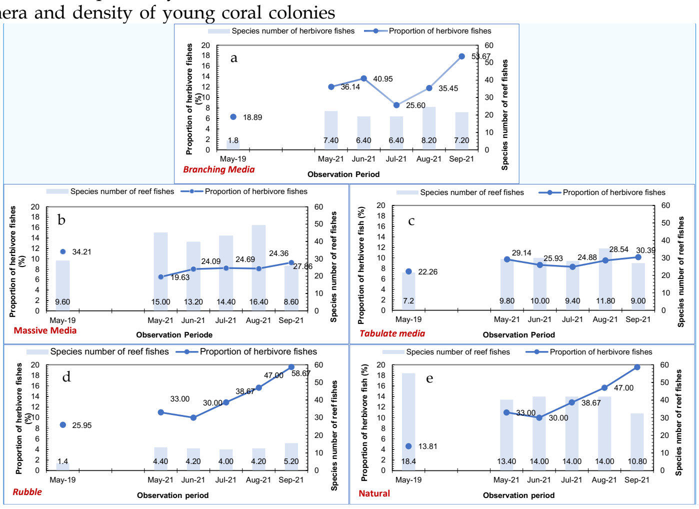

Figure 3. The dynamics of the proportion of the number of herbivorous reef fish species to the number of reef fish species on various transplant media for 5 months of observation; (a). Branching media; (b). Massive media; (c). Tabulate media; (d). Rubble; and (e). Natural.

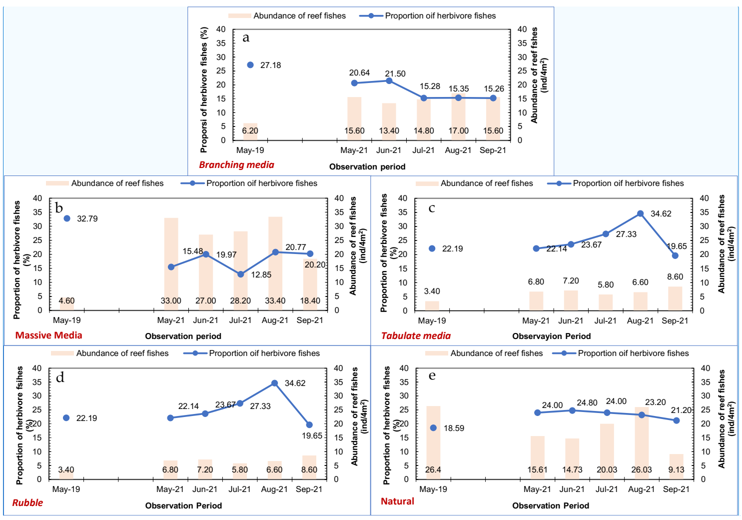

Figure 4. The dynamics of the proportion of individual herbivorous reef fish to the number of individual reef fish on various transplant media for 5 months of observation; (a). Branching media; (b). Massive media; (c). Tabulate media; (d). Rubble; and (e). Natural.

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Based on the number of individuals, the proportion of herbivorous fish ranged from 12.51 to 34.62%. A high proportion of herbivorous fish individuals was observed in the control area, namely on rubble and natural coral substrates. While the low in the other 3 substrates (branching, massive, and tabulate) ranged from 12 – 20% (Figure 4). Monthly dynamics, experience small fluctuations or can be said to be stable throughout the observations. The exception for the control substrate was rubble, which experienced a fairly large increase in August, but decreased again as in the early observations.

The number of individuals and the proportion of herbivorous fish in the waters of Liukang Loe tends to be stable, this may be due to water conditions and water quality which tend to be uniform. According to Rani et al., (2020) under the same conditions of water quality and environment, the number of individual herbivorous fish may also be the same. Elma et al., (2023) research shows that the better the brightness, the more abundance of herbivorous reef fish will be. This is due to the influence of topography and depth which provides healthier ecological conditions.

Although it tends to be stable on each type of substrate, the presence of this herbivorous fish also shows a different proportion in each type of substrate. This difference is caused by the abundance of herbivorous reef fish related to food and water conditions. Herbivorous reef fish are generally predators of benthic algae, so their distribution is related to the presence of certain groups of algae. For example, the abundance of the scrapers group will be different from that of the browser's group which indicates a difference in the distribution of the algae group consumed or preferred (Burkepile & Hay, 2011). Figure 4 also shows that there is a change in the number of individuals from each observation point from time to time. This change is also one of the bioindicators of coral ecosystem health (Cole et al., 2008; Chou & Huang, 2021). Herbivorous fish are the indicator fish to control the growth of algae that can inhibit the recruitment of new corals (Cure et al., 2021; Chou & Huang, 2021).

Diversity and Abundance of Coral Fish

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The diversity and abundance of herbivorous reef fish are one of the main components and play an important role in coral reef ecology. Its existence is very dynamic in space and time and is closely related to the dynamics of algae cover as its main food. The results of observations on various transplant media using dead coral substrate during the 5 months of observation and at the beginning of the study are presented in Figure 5.

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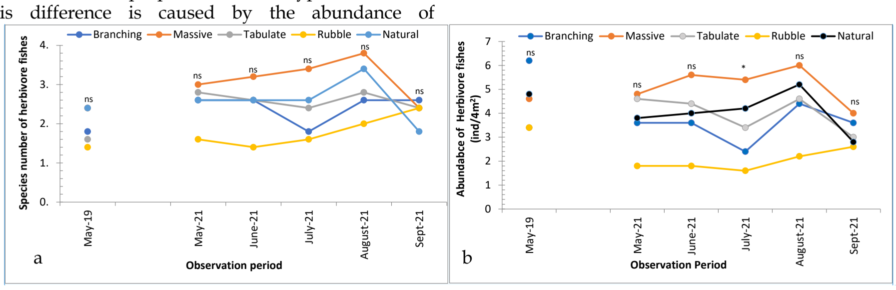

Figure 5. The dynamics of species richness (a) and abundance of herbivorous reef fish (b) on various dead coral substrates as attachment media in coral transplantation for 5 months of observation. ns: not significantly different

The spatial and temporal dynamics of the number and abundance of herbivorous reef fish have dynamics that vary greatly in temporal terms. Species richness and abundance of herbivorous reef fish had the same pattern of change in all substrates, including controls. It decreased in July and increased rapidly in August and then declined again in September (Figure 5 and Table 2). The exception is the rubble area which continues to increase until the end of the observation.

High herbivorous fish species richness was observed in branching and natural coral substrates and low in rubble substrates. Acanthuridae is a family of herbivorous fish that has the greatest number of species found (7 species) and for families Scaridae and Siganidae there are only 2 species each (Table 1 and Table 2).

Table 1. Distribution of individual herbivorous reef fish on various dead coral substrates for attachment media for transplanted coral fragments

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Family	Species	Coral dead substrates				
		Branching	Massive	Tabulate	Rubble	Natural
Achanturidae	*Acanthurus leucosternon*	1				
	A. lineatus	1		1		
	A.pyropherus	3				1
	A.nigricans	12	32	12	8	17
	Naso lituratus	2	2			1
	Ctenochaetus striatus	26	37	39	22	24
	Zebrasoma scopas	26	33	30	6	27
Scaridae	*Chlorurus microrhinos*		6		0	2
	Scarus sp	3	12		8	7
Siganidae	*Siganus virgatus*	9	4	7	2	5
	Siganus vulpinus	5	3	11	4	16
	Total	**88**	**129**	**100**	**50**	**100**

Table 2. Distribution of herbivorous reef fish individuals by month of observation in the transplant area

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Family	Species	Observation Period				
		May	June	July	August	September
Achanturidae	*Acanthurus leucosternon*	1				
	A. lineatus	1	1			
	A.pyropherus	2			1	1
	A.nigricans	18	15	17	20	11
	Naso lituratus				1	4
	Ctenochaetus striatus	33	27	29	35	24
	Zebrasoma scopas	24	31	25	30	12
Scaridae	*Chlorurus microrhinos*	1	1	1	1	4
	Scarus sp	5	7	4	8	6
Siganidae	*Siganus virgatus*	2	4	4	7	10
	Siganus vulpinus	6	11	5	9	8
	Total	**93**	**97**	**85**	**112**	**80**

Based on the abundance of herbivorous fish, massive substrate, tabulate, and natural coral had the highest abundance, and the lowest was found in the rubble area (Figure 5 and Table 1). The herbivorous fish species with the most common distribution based on the coral substrate and the month of observation were *Acanthurus nigricans*, *Ctenochaetus striatus*, and *Sebrasoma scopas*. However, the results of the analysis of variance showed that the number of species and abundance of herbivorous reef fish between dead coral substrates (including control in the form of rubble and natural coral) in each month of observation did not show a significant difference ($p > 0.05$), except for observations in July, it was found that there was a difference in the abundance of herbivorous fish ($p < 0.05$). No significant differences in the number of species and abundance of herbivorous reef fish were also observed at the start of the study (before transplant, in May 2019). The results of the analysis of variance for the number of species and abundance of herbivorous reef fish are presented in Table 3 and Table 4.

Table 3. Results of the analysis of variance on the species richness of herbivorous reef fish between substrate use in each observation period

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Obervation Period	Source of Variation	Sum of Squares	df	Mean Square	F	Sig.
May 2019	Between Groups	4,24	4	1,06	1,83	0,16
	Within Groups	11,6	20	0,58		
	Total	15,84	24			
May 2021	Between Groups	5,84	4	1,46	1,30	0,30
	Within Groups	22,4	20	1,12		
	Total	28,24	24			
June 2021	Between Groups	8,64	4	2,16	1,29	0,31
	Within Groups	33,6	20	1,68		
	Total	42,24	24			
July 2021	Between Groups	10,16	4	2,54	1,84	0,16
	Within Groups	27,6	20	1,38		
	Total	37,76	24			
August 2021	Between Groups	9,84	4	2,46	2,46	0,08
	Within Groups	20	20	1		
	Total	29,84	24			
September 2021	Between Groups	1,84	4	0,46	0,43	0,79
	Within Groups	21,6	20	1,08		
	Total	23,44	24			

Table 4. The results of the analysis of variance on the abundance of herbivorous reef fish between substrate uses in each observation peri

Obervation Period	Source of Variation	Sum of Squares	df	Mean Square	F	Sig.
May 2019	Between Groups	27,04	4	6,76	1,59	0,22
	Within Groups	85,2	20	4,26		
	Total	112,24	24			
May 2021	Between Groups	28,24	4	7,06	2,11	0,12
	Within Groups	66,8	20	3,34		
	Total	95,04	24			
June 2021	Between Groups	38,24	4	9,56	1,90	0,15
	Within Groups	100,4	20	5,02		
	Total	138,64	24			
July 2021	Between Groups	44,4	4	11,1	3,49	0,03
	Within Groups	63,6	20	3,18		
	Total	108	24			
August 2021	Between Groups	40,24	4	10,06	2,29	0,10
	Within Groups	88	20	4,4		
	Total	128,24	24			
September 2021	Between Groups	6,8	4	1,7	0,51	0,73
	Within Groups	67,2	20	3,36		
	Total	74	24			

The distribution of herbivorous reef fish both based on the substrate and the month of observation as shown in Table 1 and Table 2, shows that the families Achanturidae and Siganidae were found in each type of substrate. The Siganidae family is a family of herbivorous reef fish that are selective in choosing their food and usually live in shallow waters (Sale, 2013). This family prefers macroalgae that have wide sheets like turf algae so that the fish can tear them easily. Turf algae are the dominant macroalgae group in coral reef ecosystems (Sale, 2013; Ellis et al., 2019).

During the observation period, herbivorous fish species from the families Acanthuridae (surgeonfish), Scaridae (parrotfish), and Siganidae (rabbitfish) were found in various transplanted substrates. The results of this study confirm various similar studies in tropical waters (Tomascik & Mah, 2013). For example, similar cases were reported from San Blas Islands Panama, and Ambergris Caye, Belize with Kyposiadae composition having the same proportions as Acanthuridae, Scaridae, and Siganidae (Williams et al., 2001). Similarly, reports from subtropical waters such as the Great Barrier Reef (Cooper et al., 2019) in the waters of Lizard Island with a composition of herbivorous fish abundance for Acanthuridae 54%, Scaridae 31%, and Siganidae (14%) (Zarco-Perello et al., 2019).

The highest herbivorous reef fish species found on various substrates during the study were *Ctenochaetus striatus, Zebrasoma scopas* and *Siganus vulpinus*. This species comes from the family Achanturidae and Siganidae. Both families dominated all substrates in each observation period. On the coral reefs of Nymph Island and Turtle Group, GBR, fish from the family Achanturidae were the most important herbivores (Brandl et al., 2019), while the family Siganidae were reported to be important herbivorous fish on coral reefs in Pioneer Bay, Orpheus Island (Thépot et al., 2021).

The Role of Herbivorous Reef Fish in Controlling Algal Cover

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Herbivorous reef fish have a very important role in the stability of the ecosystem on coral reefs. One of its roles is to control the development of algae on hard substrates through a grazing mechanism so that it opens or provides a clean space for associated biota, including corals to attach or colonize. The role of herbivorous fish, in this case, their abundance on algal development, can be studied by observing the value of algal cover in each transplanted substrate every month and associated with the abundance of herbivorous reef fish, as shown in Figure 6.

In general, it shows a pattern of decreasing algal cover value with increasing herbivorous reef fish abundance or conversely increasing algal cover value when herbivorous fish abundance decreases. This pattern is visible in the control area (rubble and natural coral) and the massive substrate. The pattern in Figure 6 indicated that the association was confirmed by simple regression analysis of the relationship between the abundance of herbivorous reef fish as the X-Axis and the value of algal cover as the Y Source (Figure 7).

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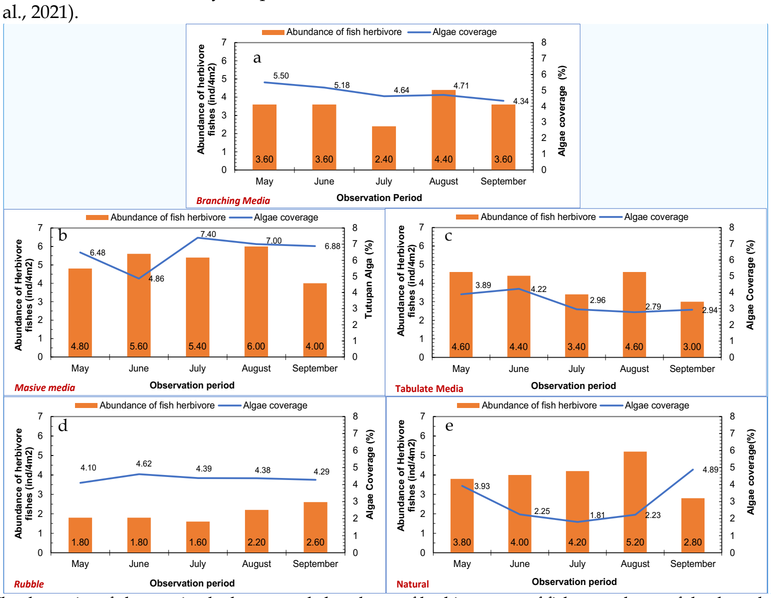

Figure 6. The dynamics of changes in algal cover and abundance of herbivorous reef fish on each use of dead coral substrate as a medium for attachment of coral fragments in transplantation activities for 5 months of observation; (a). Branching media; (b). Massive media; (c). Tabulate media; (d). Rubble; and (e). Natural

.

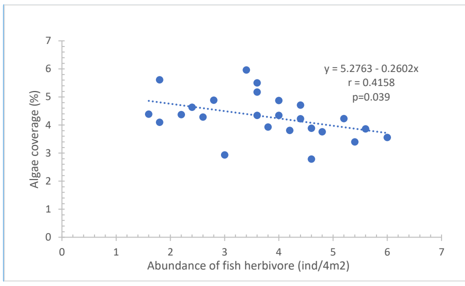

Figure 7. Scatter diagram of the relationship between herbivorous reef fish abundance and algal cover on various uses of the dead coral substrate

The results of the regression analysis give the equation y: 5.2763 - 0.260x with a correlation value of 0.4158. The regression equation proves that there is a linear relationship between the abundance of herbivorous fish and algal cover with a strength value of 41.58% and the relationship is negative. In the sense that an increase in the abundance of herbivorous reef fish will reduce the value of algal cover. Each increase in herbivorous fish by 1 individual will reduce algal cover by 0.26% in the transplant area. This relationship is significantly correlated based on the results of the analysis of variance with a probability value of 0.039 ($p < 0.05$).

The results of this study indicate that herbivorous fish is one of the factors that can control the high macroalgae cover in coral reef waters. Any reduction in herbivorous fish in sufficient nutrient conditions will cause an increase in macroalgae cover in the waters. This is in line with Zarco-Perello et al., (2019) research that the presence of herbivorous fish can be a savior of certain corals from macroalgae aggression. In the Great Barrier Reef, with the experiment, the macroalga *Sargassum siliquosum* transplanted on the reef flat did not grow well if it was confined to herbivorous fish. This study proves that the high abundance of herbivorous fish is a limiting factor in the distribution of these macroalgae. Another study in Jamaica found that by limiting the fishing of herbivores in the period 1996 – 1999, the result could reduce the percentage of macroalgae cover from 60% to 10%. In eutrophic water conditions, the role of herbivorous fish is very important in maintaining corals in competition with macroalgae (Williams et al., 2001).

High macroalgae growth can be controlled by the presence of herbivorous fish (Goreau & Hayes, 2021). Herbivorous fish are the only mechanism controlling the growth of macroalgae in coral reefs. If the growth of macroalgae is not controlled, it will automatically dominate coral reefs (McCook, 2001). In high nutrient conditions, macroalgae growth develops rapidly so that it can cause a phase shift condition (macroalgae dominance over corals). In the end, corals lost in fighting for space and light, causing a decrease in metabolism and coral growth, but with the control of herbivorous fish, macroalgae growth conditions could be suppressed (Zarco-Perello et al., 2019; Ryanskiy, 2022).

Without the presence of herbivorous fish, the recovery of coral communities will be hampered by the dominance of macroalgae that quickly occupy the space left by the corals. The high role of herbivorous fish in coral reef ecosystems causes the need for restrictions on herbivorous fishing. Overexploitation will cause high algal growth (Johnson et al., 2019; Adam et al., 2022) and will eventually cause the percentage of coral cover to decrease and the mortality of young corals to increase. In addition, the abundance of herbivorous fish was positively correlated with the addition of young coral colonies through the recruitment process (Mumby et al., 2006).

Conclusion

The proportion of herbivorous fish species in the transplant area ranged from 15.81 to 58.67% and varied both based on the month of observation and the use of dead coral substrate as attachment media. The dynamics of the number of species and abundance of herbivorous reef fish had the same dynamic pattern in all dead coral substrates but varied temporally according to the time of observation. The relationship between algal cover and herbivorous reef fish abundance showed a negative and significant relationship which confirmed that the presence of herbivorous reef fish could control or reduce the value of algal cover.

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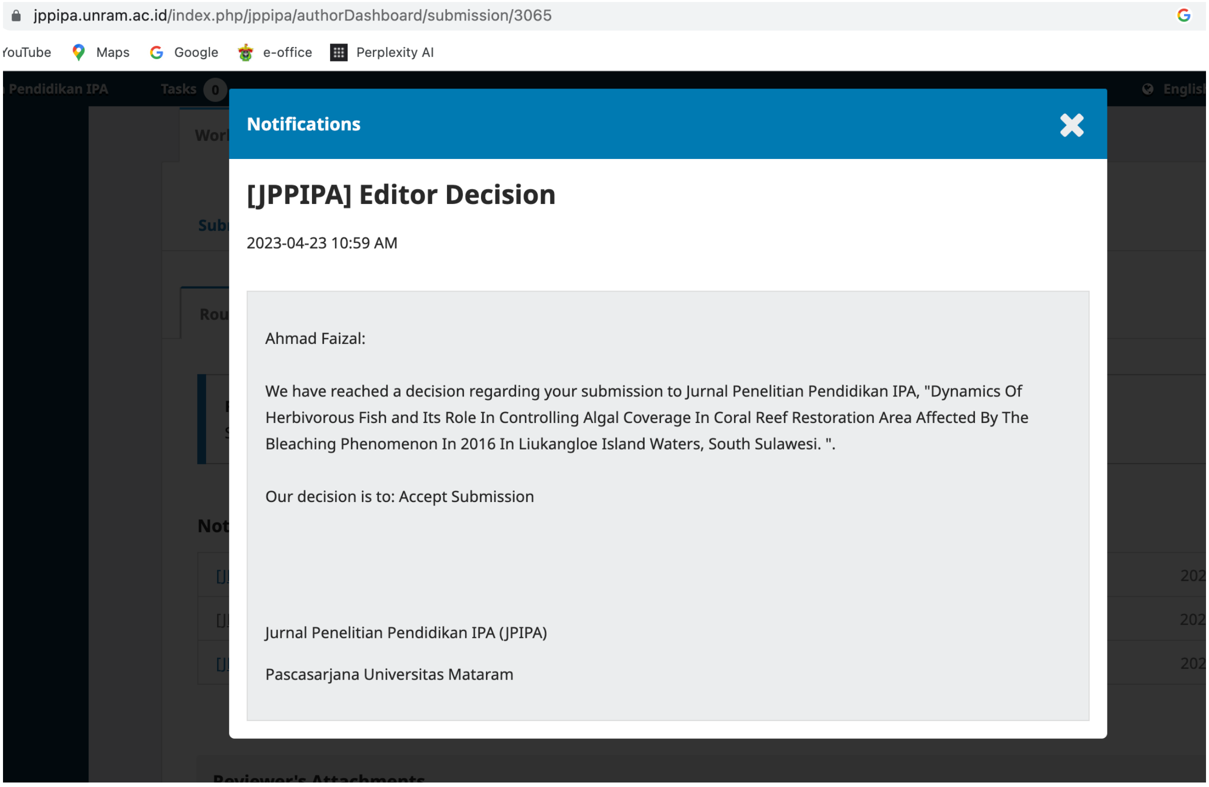
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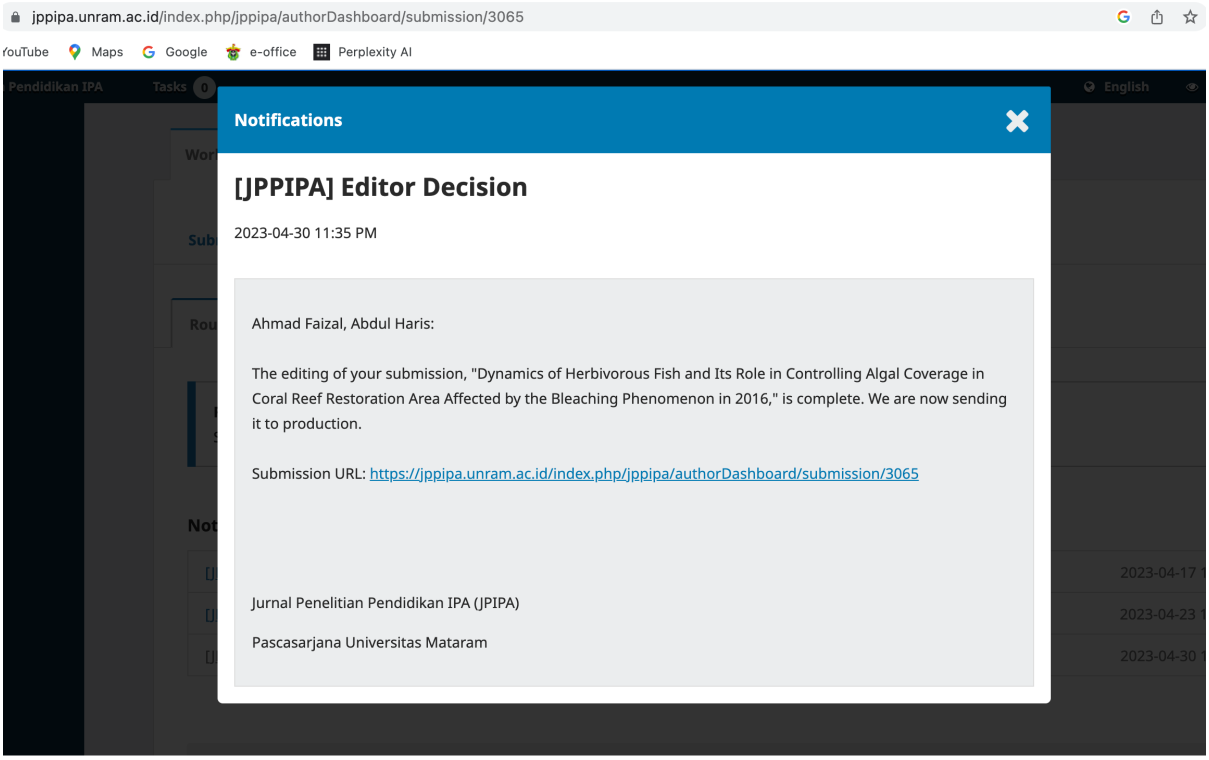

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