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Analysis of the Relationship Between Reef Fish Abundance and Coral Reef Cover in Karimun District, Riau Archipelago (Case Study: Pandan, Seranjau, Resam, Sekatip, Kelawa Besar, Kelawa Kecil, and Sebaik Islands)

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ABSTRACT

Coral reefs play an important role as habitats, spawning grounds, nutrient sources, nurseries, and shelter grounds for reef fish. Damage to coral reefs can affect the diversity and abundance of reef fish. In the waters of Karimun Regency, Riau Islands, coral reefs are under threat due to sand mining activities in the surrounding areas. This sand mining has led to magnesium and potassium pollution, which, if present in excessive amounts, can harm both coral reefs and reef fish. The objective of this study was to determine the relationship between the abundance and diversity of reef fish and coral cover. This study was conducted in September 2023 by using PIT (Point Intercept Transect) and UVC (Underwater Visual Census) methods at 10 stations where each station transect was 50 meters long and water quality data were also collected. The results showed that the average coral cover at the study sites was 53.6% which is considered good. A total of 807 reef fish individual were identified across the 10 stations, belonging to 4 families and 14 species. The reef fish diversity index (H') ranged from 0.917 to 1.502, categorized as low to medium. The abundance of reef fish ranged 0.100 - 0.980. The correlation test between coral cover and reef fish diversity yielded a value of -0.021, indicating a weak negative relationship. Meanwhile, the correlation between

coral cover and reef fish abundance showed a value of 0.192, suggesting a positive but weak relationship.

INTRODUCTION

Indonesia is one of the countries located within the "Coral Triangle," a region with a very high distribution of coral reefs and biodiversity **(Mujiono & Oktaviani, 2021)**. It has a total coral reef area of around 2.5 million hectares **(Hadi *et al.*, 2020)**. In 2019, data collected from 1,153 reefs showed that approximately 390 reefs (33.82%) were in the poor category, 431 reefs (37.38%) in the fair category, 258 reefs (22.38%) in the good category, and 74 reefs (6.42%) in the excellent category **(Hadi *et al.*, 2020)**. Coral reefs play an imperative role as habitats, spawning grounds for fish, sources of nutrients for marine biota, nurseries for the growth of fish eggs and larvae, and as sheltering ground **(Ramadhani *et al.*, 2015)**. Based on the trophic level also called the food chain level, reef fish have a very important function in the food chain **(Zurba, 2019)**. A coral cover percentage above 75% indicates that the condition of the coral reef ecosystem is very good **(Muqsit *et al.*, 2016)**. A healthy coral reef is an indicator of the marine ecosystem biota community **(Zurba, 2019)**. Sponge biota, for example, sponges that live in waters can be used as biological indicators of environmental degradation and indicators of healthy coral reef ecosystems **(Dewi, 2010)**.

Indonesia has around 2,000 species of reef fish, belonging to 113 families that depend on coral reef ecosystems **(Allen & Aldrim, 2003)**. Coral reef morphology such as sheet shape, branching, and others are used as a place of protection, hiding, and self-defense by reef fish from predators **(Tambunan *et al.*, 2020)**. Coral reef fish communities are divided into three categories: First, target fish communities, which represent the primary catch of fishermen because these fish are consumed and have high economic value **(Edrus *et al.*, 2017)**. Second, major reef fish communities that mostly play a role in the food chain of coral reef ecosystems **(Dewi *et al.*, 2018)**. The presence of reef fish, especially the indicator fish, is an indicator of life in the coral reef ecosystem **(Harsindhi *et al.*, 2020; Mujiyanto *et al.*, 2021)**. The waters of Karimun Regency, Riau Islands are threatened by sand mining activites around the islands. Sand mining has caused pollution, magnesium, and potassium on Karimun Island **(Irzon, 2021)**. Magnesium and potassium are elements that can be harmful to coral reefs and reef fish when present in excessive concentrations **(Permana *et al.*, 2021)**. Mining tailings sites have been shown to contain these metals **(Abaka-Wood *et al.*, 2019; Irzon *et al.*, 2020)**. Sand mining on Karimun Island, through sand suction activities, can stir up mud at the seabed, potentially increasing turbidity and suspended solids both within the mining area and its surroundings **(Sofiyani *et al.*, 2012)**, which can disrupt the coral reef ecosystem in the region. According to **Harahap *et al.* (2021)**, sedimentation is also a prominent indication of the cause of coral disease.

Coral Watch data show that the majority of coral reefs in the Riau Islands from 2018 to 2024 were classified in the watch to warning category, and this area has expanded further in 2024 **(NOAA, 2024)**. This means that coral reefs on the Riau Islands including Karimun Regency must be monitored to determine the distribution of coral reef cover. The Karimun Regency area does not have much information on coral reef cover, abundance, and diversity. Therefore, research and publications are needed to enrich this information, especially with the factors that can threaten the existence of coral reefs and reef fish in the region and prove the correlation between reef fish diversity and abundance to coral reef cover.

MATERIALS AND METHODS

1. Study area

This research was conducted in Karimun Regency, Riau Islands. Karimun Regency is located at coordinates 00˚24'36" North to 01˚13'12" North and 103˚13'12" East to 104˚00'36" East with a marine area within a four-mile boundary measured from the coastline towards the open sea and/or towards archipelagic waters. The study area covered the Seranjau Island group, which includes Seranjau Island, Pandan Island, Resam Island, Sekatip Island, Kelawa Besar Island, Kelawa Kecil Island, and Sebaik Island. This research was conducted from September to November 2023, and data collection was carried out on September 2023.

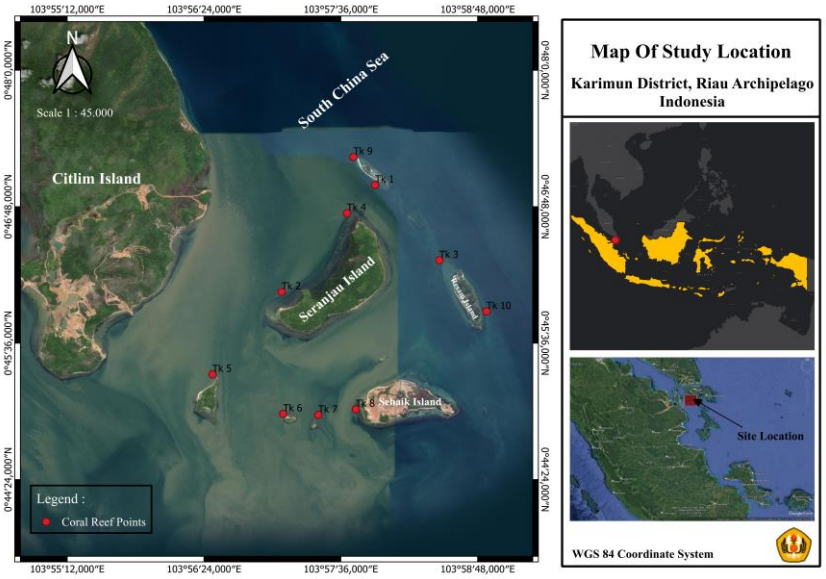

Fig. 1. Map of sampling locations in Karimun Regency, Riau Island

Observations were carried out at 10 sampling locations around the Seranjau Island group (Fig. 1). The research method used is the survey method. The data obtained were reef fish, coral reef, and water quality data. The data obtained produce quantitative and

qualitative data including the diversity and the abundance of reef fish, the percentage of coral reef cover, and the correlation of reef fish abundance with the condition of coral reef cover which were processed using data analysis. Qualitative data were obtained through direct field observations of coral conditions at predetermined points.

2. Procedures

Water quality measurement

Measurement of physicochemical parameters was conducted *in situ*, with three repetitions taken directly at each observation station. Parameters taken include water temperature data using a thermometer, salinity using a refractometer, water brightness using a secchi disk, water acidity using a pH meter, and dissolved oxygen levels using a DO meter.

Reef fish assemblages

Reef fish data collection was conducted using the Underwater Visual Census (UVC) method, which employs a 50-meter-long transect with a 2.5-meter distance on each side. The abundance of fish of each species began to be calculated with a monitoring distance limit of 2.5m on the left and right sides of the transect **(English *et al*., 1997)**. The width of the transect limit of 2.5m is the standard limit of underwater vision using a diving mask **(Dimara *et al*., 2020)**. Fish not identified underwater were documented and later re-identified using a literature book. Data collection was conducted between 08:00 AM and 4:00 PM, depending on the sequence of stations from Station 1 to Station 10.

Coral reef assemblage

Observations of coral reef cover percentages were conducted using the Point Intercept Transect (PIT) method. This method is one of the methods developed for monitoring the status of live corals and other supporting biota. This technique can be used to easily and quickly estimate the condition of coral reefs in an area based on the percentage cover of live corals **(Fadhillah *et al*., 2021)**. Upon implementation, this method uses observation points every 0.5 meters. The recorded coral data included growth forms based on coral life forms.

3. Data analysis

Several parameters were used to measure and evaluate biological and ecological diversity, including the percentage of coral reef cover **(English *et al*., 1997)**, coral mortality index, reef fish abundance index **(Labrosse *et al*., 2002)** and the Shannon-Wiener Diversity Index (H'). Statistical data analysis was carried out using Pearson Correlation Coefficient Analysis assisted by the Microsoft Excel application. Pearson correlation is a straightforward correlation that comprise only one dependent variable and one independent variable **(Safitri, 2016)**. The formula used was as follows **(Pearson, 1990)**:

$$r = \frac{n\sum xy - \left(\sum x\right)\left(\sum y\right)}{\sqrt{\left(n\sum x^2 - \left(\sum x\right)^2\right)\left(n\sum y^2 - \left(\sum y\right)^2\right)}}$$

Where:

r = Pearson correlation

n = Number of transects

x = X variable value (percentage live coral cover)

y = Y variable value (reef fish abundance)

RESULTS

The waters in a specific area have different characteristics compared to other waters. Various physical and chemical factors can recognize this. The temperature in the waters of Seranjau Island and its surroundings is considered quite good for coral growth, as research shown that temperatures between 28 and 32°C are the ideal temperatures for coral growth and reproduction **(Hoey *et al*,. 2016; Harvey *et al*., 2018)**. This suggests that the temperature range in the waters of Seranjau Island and its cluster, which is between 30-32°C, is suitable for coral growth and reproduction. In addition, the high temperature of the Seranjau waters and its cluster may be attributed to the timing of data collection in September, when Indonesia experiences the late dry season transitioning to the rainy season **(Setiawan *et al*., 2013; Rahman *et al*., 2019)**.

The salinity of the waters of Seranjau Island and its cluster ranges from 27 - 30‰, with the average being 29‰, Sekatip Island showing the highest value of 30‰ and Kelawa Kecil Island showing the lowest value of 27‰. According to Kepmen LH No. 51 of 2004, the value of salinity for maximum growth tolerance of marine life is up to 33-34‰ **(Kepmen, 2004)**. Nevertheless, the adaptability of marine organisms also plays an essential role in the growth of marine life. The salinity tolerance of coral animals is between 27 and 40‰, which remains within a suitable range for other marine life. The ideal salinity for coral growth and development is between 25 and 40‰ **(Souhokka & Patty, 2013)**. The value of salinity in the waters of Seranjau and its cluster can be concluded to be quite good for the growth and development of coral reefs.

The water brightness of Seranjau Island and its cluster ranged from 0.8 - 1.9m, with an average of 1.31 meters. Resam Island and Seranjau 2 Island have the lowest brightness of 0.8 meters, while Seranjau 1 Island has the highest brightness of 1.9 meters. According to Kepmen LH No. 51 Year 2004, the brightness or water clarity for the

maximum growth of marine biota is >5 meters. As a whole station, the brightness in the waters of Seranjau Island and its cluster is fairly low, likely due to high turbidity caused by sand mining activities in the surrounding area.

Dissolved oxygen (DO) in the waters of Seranjau Island and its surrounding clusters ranged from 5.9 - 8.6mg/ l, with an average DO of 7.65mg/ l. The lowest DO value (5.9mg/ l) was at Station 2, Seranjau Island 1, while the highest DO value (8.6mg /l) was at Resam Island. The assessment of the DO parameter of Seranjau Island waters and its cluster is in very good condition exceeding the standard of dissolved oxygen content> 5mg/ l for biota and tourism Kepmen LH Number 51 of 2004.

The degree of acidity (pH) in the waters of Seranjau Island and its cluster ranged from 7.45 - 8.7, with an average pH of 8.23. Resam Island has the highest pH of 8.7 and Kelawa Kecil Island has the lowest pH of 7.45. The pH parameter value of the waters of Seranjau Island and its cluster is in normal condition for the growth tolerance of marine biota, according to the pH standard of 7 - 8.5 for biota and tourism Kepmen LH Number 51 of 2004. In general, the pH value of seawater is above 7, which means it is alkaline, but under convinced circumstances, the pH value can drop below 7, making it acidic, and aquatic organisms are very sensitive to changes in pH. Based on this threshold, the waters of Seranjau Island and its cluster are suitable for the growth of marine biota because they have an average pH value above 7, indicating that the waters is alkaline.

Table 1. Physiochemical parameters of seawaterquality in the waters of Seranjau Islands

Station		Station Coordinates		Water Quality Parameters				
No.	**Names (Island)**	**Lat.**	**Long.**	**Temp. (ºC) (± 0.1)**	**Salinity (‰) (± 0.1)**	**Brightness (m) (± 0.1)**	**DO (mg/l) (± 0.1)**	**pH (± 0.1)**
Tk 1	Pandan	0.78319	103.96502	32	28	1.70	7.3	8.50
Tk 2	Seranjau	0.76751	103.95135	30	29	1.90	5.9	8.60
Tk 3	Resam	0.77214	103.97441	30	29	0.80	8.6	8.70
Tk 4	Seranjau 2	0.77905	103.96090	30	29	0.80	7.9	8.50
Tk 5	Sekatip	0.75542	103.94124	30	30	1.10	7.9	8.15
Tk 6	Kelawa Besar	0.74963	103.95157	30	29	1.10	7.8	8.05
Tk 7	Kelawa Kecil	0.74948	103.95671	30	27	1.10	7.6	7.45
Tk 8	Sebaik	0.75031	103.96219	30	29	1.60	7.7	7.50
Tk 9	Pandan 2	0.78729	103.96185	31	28	1.50	7.9	8.45
Tk 10	Resam 2	0.76466	103.98130	31	28	1.50	7.9	8.45
Average				30	29	1.31	7.7	8.23

1. Coral reef cover condition in Karimun Waters

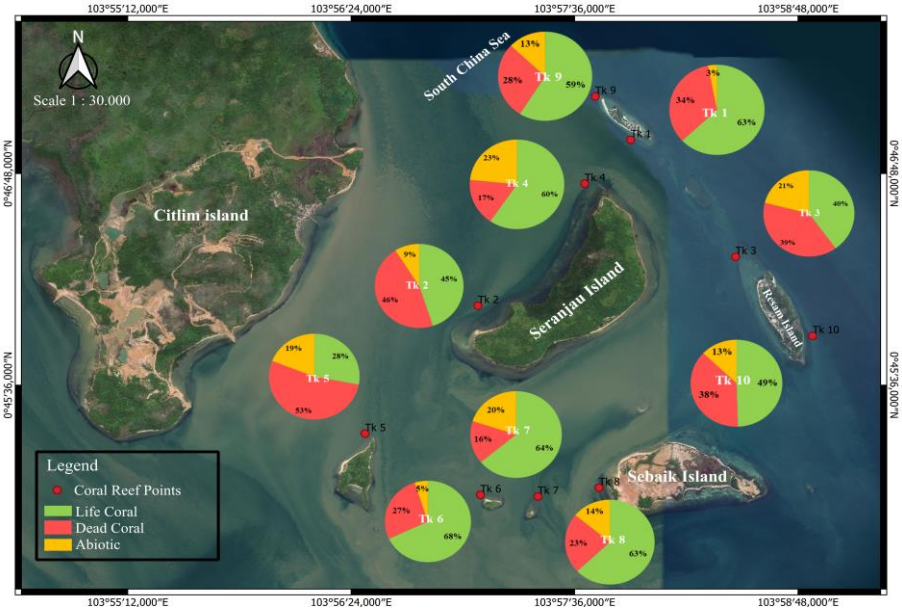

Fig. 2. Coral reef cover in Karimun Waters

The results of dives at 10 observation stations of coral cover on the Seranjau Island group based on the live corals' category in the good and moderate categories (Fig. 2). The good category is found on Pandan corals, Seranjau 2 corals, large Kelawa corals, small Kelawa corals, Sebaik corals, Pandan 2 corals and Resam 2 Island corals with a live coral value ranging from 50 - 68% (Table 2). While coral cover in the medium category was found at Seranjau coral, Resam coral, and Sekatip coral, the value of live corals ranged from 28 - 45%. However, at some points of the station under study, corals were in a damaged condition (dead coral) with the highest value of 53% damage percentage (Sekatip coral). Sand mining activities in the waters of Citlim Island clearly affect the longevity of the coral reefs.

Table 2. Coral reef cover percentage

Station		Coral Types (Lifeform)					Percent coverage (%)	Category	∑ Species
Code	Names (Island)	Hard coral	Dead coral	Algae	Other fauna	Abiotic			
Tk 1	Pandan	47	34	0	16	3	63.0	Good	9
Tk 2	Seranjau	31	46	0	14	9	45.0	Medium	7
Tk 3	Resam	30	39	0	10	21	40.0	Medium	7
Tk 4	Seranjau 2	37	16	6	19	22	56.0	Good	7
Tk 5	Sekatip	20	53	0	8	19	28.0	Medium	11
Tk 6	Kelawa Besar	32	27	0	36	5	68.0	Good	7
Tk 7	Kelawa Kecil	47	16	0	17	20	64.0	Good	7
Tk 8	Sebaik	50	23	0	13	14	63.0	Good	10
Tk 9	Pandan 2	40	28	0	19	13	59.0	Good	8
Tk 10	Resam 2	41	38	0	9	13	50.0	Good	9
						Average	53.6	Good	

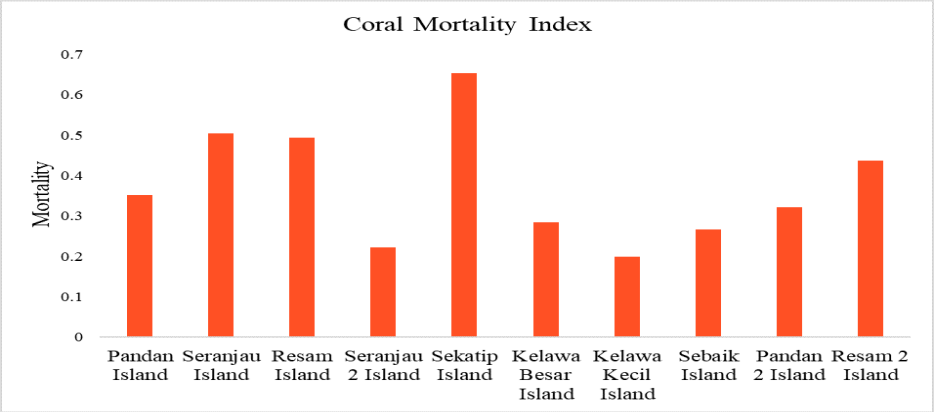

Fig. 3. Coral mortality index

Fig. (3) shows that the measure of the grade of damage to coral reefs is obtained through the mortality index (MI) approach. The mortality index at 10 stations of the Seranjau Island cluster shows that the highest level of coral reef damage is at the location of sekatip coral, with a mortality index of 0.654, and the lowest at Kelawa kecil coral (Station 7) with a value of 0.2 (Fig. 3). Averaged value of coral mortality index in the Seranjau Island cluster is 0.374. This indicates that the mortality index at all stations is quite high which may be caused by the presence of sand mining activities in these areas. The high mortality rate of corals can be caused by differences in light intensity that reaches the reef which will affect the rate of photosynthesis and the formation of calcium carbonate in coral growth by zooxanthellae **(Joni *et al.*, 2017)**.

2. Reef fish condition in Karimun Waters

Table 3. Reef fish condition in the waters of Seranjau Island and its cluster

Station		**Station coordinates**		**Ecological analyses of reef fish**			
Code	Name (Island)	Lat.	Long.	∑ Total (Ind)	Abundance (Ind/m^2)	∑ Species	Diversity Index (H')
Tk 1	Pandan	0.78319	103.96502	57	0.228	4	1.368
Tk 2	Seranjau	0.76751	103.95135	107	0.428	7	1.283
Tk 3	Resam	0.77214	103.97441	54	0.216	4	1.256
Tk 4	Seranjau 2	0.77905	103.96090	31	0.124	5	1.501
Tk 5	Sekatip	0.75542	103.94124	47	0.188	3	1.029
Tk 6	Kelawa Besar	0.74963	103.95157	23	0.092	3	1.091
Tk 7	Kelawa Kecil	0.74948	103.95671	245	0.980	4	1.096
Tk 8	Sebaik	0.75031	103.96219	25	0.100	3	0.917
Tk 9	Pandan 2	0.78729	103.96185	168	0.672	6	1.267
Tk 10	Resam 2	0.76466	103.98130	50	0.200	5	1.394
Total				807			

In the waters of Seranjau Island and its cluster, the identification results of reef fish at 10 observation stations found around 807 reef fish individuals, comprising of 4 families and 14 types (species) of reef fish. The largest number of individuals is found at Station 7, namely on Kelawa Kecil Island, with the highest abundance level of 0.980 individuals/m², which the Pomacentridae family dominates with the number of fish individuals reaching 245 individuals (Table 4). While, the lowest number of individuals with the lowest abundance level was found on Kelawa Besar Island at only 0.092 individuals/m², which only contained around 23 fish individuals throughout the station. The distribution of reef fish abundance can be seen in Fig. (4).

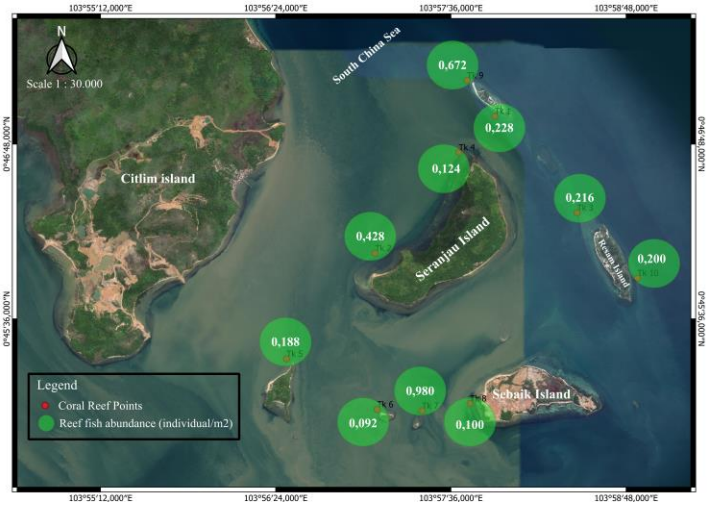

Fig. 4. Distribution of reef fish abundance

Fig. 5. Distribution of reef fish diversity

At station point 2, Seranjau Island, there are the largest fish species with 7 species at that point, and station points with the lowest species types are on Sekatip Island, Kelawa Besar Island, and Sebaik Island. The diversity index (H') of reef fish obtained at almost all stations is the same as the medium category, between 1.029 - 1.501, except at

station point 8, Sebaik Island with a diversity index (H') of only 0.917 (Table 2). The highest fish diversity index is at station 4, Seranjau 2 Island, which has a value of 1.501, a total of 5 fish species, and a total of 31 fish individuals. Based on the value of the reef fish diversity index obtained, it can be concluded that reef fish diversity is classified as moderate where $1 \leq H' \leq 3$, (moderate diversity, moderate distribution, moderate community stability).

The composition of reef fishes in the waters of Seranjau Island and its cluster are shown in Table (4)

Table 4. Reef fish condition in the waters of Seranjau Island and its cluster

No.	Region (Island)	Station Code	Family	Species	Count
1	Pandan	Tk 1	Pomacentridae	*Chromis ternatensis*	13
				Pomacentrus buroughi	19
			Mullidae	*Parupeneus barberinus*	12
				Parupeneus macronemus	13
		Tk 9	Chaetodontridae	*Heniochus chrysostomus*	1
			Pomacentidae	*Chromis amboinensis*	58
				Chromis ternatensis	24
				Neopomacentrus bankieri	73
			Mullidae	*Parupeneus macronemus*	9
			Labridae	*Halichoeres hortulanus*	3
2	Seranjau	Tk 2	Pomacentridae	*Chromis ternatensis*	52
				Pomacentrus buroughi	3
				Amphiprion ocellaris	8
				Neopomancentrus bankieri	36
				Premnas Cielatus	2
				Abudefduf septemciatus	2
			Chaetodontidae	*Chelmon rostratus*	4
		Tk 4	Pomacentridae	*Chromis ternatensis*	3
				pomacentrus buroughi	5
				Amphiprion ocellaris	4
			Mullidae	*Parupeneus barberinus*	8
				Parupeneus macronemus	11
3	Resam	Tk 3	Pomacentridae	*Chromis ternatensis*	13
				pomacentrus buroughi	25
			Mullidae	*Parupeneus barberinus*	6
				Parupeneus macronemus	10
		Tk 10	Pomacentridae	*Chromis amboinensis*	13
				Chromis ternatensis	9

				Neopomacentrus bankieri	21
			Mullidae	*Parupeneus macronemus*	3
			Chaetodontidae	*Chaetodon octofasciatus*	4
4	Sebaik	Tk 8	Pomacentridae	*Chromis ternatensis*	3
				Chromis amboinensis	15
			Mullidae	*Parupeneus macronemus*	7
5	Kelawa Kecil	Tk 7	Pomacentridae	*Chromis ternatensis*	117
				Neopomacentrus bankieri	79
				Pomacentrus alexanderae	45
			Mullidae	*Parupeneus barberinus*	4
6	Kelawa Besar	Tk 6	Pomacentridae	*Chromis ternatensis*	7
			Mullidae	*Parupeneus macronemus*	7
				Parupeneus barbarinus	9
7	Sekatip	Tk 5	Pomacentridae	*Chromis ternatensis*	18
				Neopomacentrus bankieri	21
			Mullidae	*Parupeneus barberinus*	8

DISCUSSION

The results of the correlation analysis between coral reef cover and reef fish abundance in the waters of the Seranjau Island group obtained a relatively low value, namely (r) 0.192. This value indicates that in the waters of the Seranjau Island group of Karimun Regency, there is a positive correlation between coral reef coverage and reef fish. The existence of a positive relationship between coral cover and reef fish abundance, means that changes in coral cover will also result in changes in fish abundance **(Iskandar *et al.*, 2021)**. However, the low correlation value implies that there is no significant influence between coral reef cover and reef fish.

The results of the correlation examination between coral reef cover and reef fish abundance in the waters of the Seranjau Island group obtained a relatively low value, namely (r) -0.021. This value shows that in the waters of the Seranjau Island group of Karimun Regency, the association between coral reef cover and reef fish is negative. However, with a value that tends to be close to 0, this indicates that the negative correlation does not significantly influence coral reef cover and reef fish diversity.

A study conducted by **Sudarmaji and Efendy (2021)** in Noko Island waters concluded a low association among coral reef cover and reef fish. Another research also showed that there was no major influence between coral reef cover and reef fish, with a correlation value (r) of 0.3903 **(Riyantini *et al.*, 2023)**. **Nugraha *et al.* (2020)** stated that the correlation (r) among coral reef cover and reef fish abundance presented low correlation of 0.0182. This research is also in line with **Hasdar (2017)** research conducted on the Spermonde Islands showing that the value of Pearson's correlation (r)

was 0.0000, with a significance rate of 1.0000, which is >0.05, that gave relatively the same conclusion, indicating that there was no significant correlation between coral cover and reef fish abundance.

One factor that determineshes abundance of reef fish other than by living or dead corals is habitat complexity **(Rani *et al*., 2019)**. There are many dead coral with algae (DCA) and abiotic components such as sand or Rutbble on the transect, which causes some coral cover to have a smaller percentage than the value of reef fish abundance, so the value of the correlation becomes low. Coral reef regions consist not only of corals that serve as habitats for reef fish but also include sandy areas, slopes or cliffs, algae, rocky terrains, and shallow waters that provide habitats for these fish.

The presence of reef fish can be influenced by biotic and abiotic factors, in addition to the richness biota of the coral reef ecosystem can also affect the presence of reef fish such as substrate variables, the presence of other biota, as well as by oceanographic factors **(Fitriadi *et al*., 2017; Erdana *et al*., 2022)**. Biotic factors that can affect this include competition, predation, and distribution of reef fish **(Munday *et al*., 2001)**. While abiotic factors that affect include current, depth and brightness **(Pinheiro *et al*., 2013)**. The varying pattern of reef fish populations do not always coincide with those of coral cover. The fluctuation in the number of each fish family is probably caused by both human and natural disruptions in the presence of fish in the waters around the Seranjau Island group. Anthropogenic activities such as fishing activities have a very close relationship with the sustainability of coral reef ecosystems and the aquatic ecology, including coral reef ecology, can be significantly influenced by this activities **(Luthfi *et al*., 2017)**.

The study findings indicated that the presence of reef fish in a particular location may be impacted by variables like the intricacy of coral formations (rugosity), environmental factors, and nutrient levels in the water **(Prato *et al*., 2017)**. Habitat complexity (rugosity) of corals is an important variable affecting fish populations. Likewise, more complex habitats generally provide more space for shelter for fish to avoid predators **(Nugraha *et al*., 2020)**. Other studies have also shown that coral rugosity affects reef fish abundance in coral reef ecosystems with a correlation value (r) reaching 0.7458 **(Ariyanti *et al*., 2022)**.

A study by **Ilyas *et al.* (2017)** reported a unidirectional or positive relationship between target fish abundance and coral growth forms, although the correlation was weak. Similarly, **Ghiffar *et al.* (2017)** found that an increase in coral reefs was associated with greater target fish diversity, but the relationship was not statistically significant. Research conducted in the waters of Bawean Island also found no clear link between coral cover percentage and coral diversity, likely due to the condition of the coral reef ecosystem at the time of data collection; in fact, higher coral cover was observed to coincide with lower diversity **(Handoko, 2008)**. **Putra *et al.* (2015)** found a weak positive correlation (r = 0.181) between soft coral cover and fish abundance, which was

also not statistically significant due to the low correlation value. Consistent with these findings, **Ernaningsih *et al.* (2022)** reported that live coral cover showed a negative correlation with both fish abundance and species diversity.Research conducted in Mexico's TEP revealed that certain species were more commonly found on rocks rather than coral reefs. Additionally, some of these species were situated beyond the coral reef core area where fish gather **(Olán-González *et al.*, 2020)**. These fish species are prevalent across various functional spaces, indicating that coral reefs encompass a functionally diverse range of substrates when compared to other coral reefs. The structural complexity produced and the fish assemblages that corals sustain are determined by the kind of coral that they support **(Alvarez-Filip *et al.*, 2013)**. In that study, the coral community in the Tropical Eastern Pacific (TEP) was dominated by species of the genus *Pocillopora*—branching corals that, despite their morphological complexity, form reefs with low rugosity values. These reefs may provide limited shelter or feeding areas for fish larger than a few centimeters (>5cm). In contrast, the rocky reefs of Mexico's TEP, characterized by numerous holes, crevices, and rocks of various sizes, offer a more complex three-dimensional structure **(Aburto-Oropeza *et al.*, 2015)**. Research indicates that rocky reefs in the TEP exhibit higher rugosity than coral reefs, which contributes to supporting both the functional and taxonomic diversity of fish by creating a wider range of habitats **(Olán-González *et al.*, 2020)**. The structure of reef fish communities is strongly influenced by the environment in which they live forming strong associations, where both the quality of the water body and the variation in habitat or substrate strongly favor community survival. Diversity is also shaped by variations in habitat or substrate that form evenness among populations **(Edrus *et al.*, 2017)**. Differences in abundance and richness of reef fish species are closely related to environmental conditions in the water area. In addition, food availability conditions are also an important factor affecting the presence of reef fish in an area **(Andrimida & Hardiyan, 2022)**.

Research proves that variations in ecological condition have a major effect on species richness , especially on species correlated with physical and chemical parameters of seawater , depth, and benthic diversity **(Herawati *et al.*, 2021; Utama *et al.*. 2022; Wulandari *et al.*, 2022)**. This is supported by the findings of a study analyzing the relationship between coral reef abundance and fish populations, which found that 78.6% of the variation in fish abundance was influenced by factors not included among the tested variables **(Bintoro *et al.*, 2023)**. Other components, such as food availability, the presence of safe shelters, and the absence of predators in coral reef areas, also contribute to the high prevalence of coral reefs and the diversity of reef fish, which is often correlated with high coral cover (**Rosdianto *et al.*, 2021)**. Additionally, the type of substrate plays a significant role in reef fish diversity. Even when coral cover is low, a high reef fish diversity index can still be observed due to the influence of abiotic components. This was demonstrated in a study conducted in the waters of Gosong

Pramuka, where the presence of abiotic elements such as sand, rubble, and dead coral algae (DCA) within the transects led to relatively low coral cover but a fairly high diversity of reef fish **(Riyantini *et al.*, 2023)**.

The composition of coral reef fish may also be affected by other factors, including benthic characteristics, coral life forms, reef edge types, habitat connectivity, and fishing pressure **(Faricha *et al.*, 2020)**. For example, branching corals like *Pocillopora* can support large populations of small coral reef fish due to the many spaces between their branches **(Darling *et al.*, 2017; Brandl *et al.*, 2018)**. This is consistent with research covering Komodo Island National Park, East Nusa Tenggara, which found that these branching forms provide herbivorous fish with shelter from predators—a key factor in their association **(Hadi *et al.*, 2023)**.

It is also important to note that although *Pocillopora*-dominated reefs may support less overall species richness compared to other reef ecosystems, they can still significantly influence fish assemblage diversity, especially if these reefs are damaged or degraded **(Arias-Godínez *et al.*, 2019)**. Research further shows that coral reefs enhance fish diversity primarily through their complex and structurally rich habitats **(Darling *et al.*, 2017; Richardson *et al.*, 2017)**.

CONCLUSION

The condition of coral reefs of the Seranjau Island Cluster, Karimun Regency, Riau Islands, found that of the 10 observation station points, 3 of them were classified as moderate and 7 others were classified as good. The percentage of coral reef cover has values ranging from 28% - 68%. Reef fish in the waters of Seranjau Island Cluster were found as many as 807 individuals consisting of 4 families and 14 species The abundance of reef fish in the waters of Seranjau Island Cluster ranged from 0.092 - 0.980 ind/m2. The diversity index (H') in the waters of the Seranjau Island Cluster ranges from 0.917 - 1.502 with criteria classified as low to moderate diversity. The correlation of the percentage of coral reef cover with reef fish abundance has a positive relationship but is classified as low with a value of 0.192. While the correlation of the percentage of coral reef cover with reef fish diversity has a negative relationship but is classified as very low with a value of -0.021. This means that in this research, there is a positive correlation between coral reef cover and reef fish abundance, but the correlation between coral reef cover and reef fish diversity is negatively correlated, and neither correlation has a significant effect.

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REFERENCES

Abaka-Wood, G.B.; Zanin, M.; Addai-Mensah, J. and Skinner, W. (2019). Recovery of rare earth elements minerals from iron oxide–silicate rich tailings – Part 2: Froth flotation separation. *Minerals Engineering*, 142. https://doi.org/10.1016/j.mineng.2019.105888

Aburto-Oropeza, O.; Ezcurra, E.; Moxley, J.; Sánchez-Rodríguez, A.; Mascareñas-Osorio, I.; Sánchez-Ortiz, C.; Erisman, B. and Ricketts, T. (2015). A framework to assess the health of rocky reefs linking geomorphology, community assemblage, and fish biomass. Ecological Indicators, 52, pp.353–361. https://doi.org/10.1016/j.ecolind.2014.12.006

Allen GR; Aldrim M. (2003). Coral Reef Fishes of Indonesia. ZoologicalStudies. 42:1–72.

Alvarez-Filip L; Carricart-Ganivet JP; Horta-Puga G; Iglesias-Prieto R. (2013). Shifts in coral-assemblage composition do not ensure persistence of reef functionality. Sci Rep. 3. https://doi.org/10.1038/srep03486

Andrimida, A. and Hardiyan, F.Z. (2022). Trophic structure of coral fishes and its relationship with bottom substrate conditions in Sempu Strait, Indonesia. Journal of Fisheries and Marine Research, 6(1):41–54. https://doi.org/10.21776/ub.jfmr.2022.006.01.6

Arias-Godínez, G.; Jiménez, C.; Gamboa, C.; Cortés, J.; Espinoza, M. and Alvarado, J.J. (2019). Spatial and temporal changes in reef fish assemblages on disturbed coral reefs, north Pacific coast of Costa Rica. Marine Ecology, 40(1). https://doi.org/10.1111/maec.12532

Ariyanti, L.A.S.; Novitasari, H.; Insafitri, I. and Nugraha, W.A. (2022). Closure, coral reef rugosity and coral fish abundance in northern waters of Bangkalan. Jurnal Kelautan Tropis, 25(2):202–212. https://doi.org/10.14710/jkt.v25i2.13769

Bintoro, G.; Isdianto, A.; Harahab, N.; Kurniawan, A.; Wicaksono, A.D.; Mahardithа, R.; Fathah, A.L.; Putri, B.M.; Haykal, M.F.; Asadi, M.A. (2023). Reef fish monitoring as a coral reef resilience indicator in the Sempu Strait, South of East Java, Indonesia. Biodiversitas, 24(9):4950–4959. https://doi.org/10.13057/biodiv/d240938

Brandl, S.J.; Goatley, C.H.R.; Bellwood, D.R. and Tornabene, L. (2018). The hidden half: ecology and evolution of cryptobenthic fishes on coral reefs. Biological Reviews, 93(4):1846–1873. https://doi.org/10.1111/brv.12423

Darling, E.S.; Graham, N.A.J.; Januchowski-Hartley, F.A.; Nash, K.L.; Pratchett, M.S. and Wilson, S.K. (2017). Relationships between structural complexity, coral

traits, and reef fish assemblages. Coral Reefs, 36(2):561–575. https://doi.org/10.1007/s00338-017-1539-z

Dewi, A.S. (2010). Stress response in sponges and its potential application as biomonitor of pollutants in coral reef ecosystems. Squalen Bulletin of Marine and Fisheries Postharvest and Biotechnology, 5(3):92–100. https://doi.org/10.15578/squalen.v5i3.52

Dewi, C.S.U.; Sukandar, and Harsindhi, C.J. (2018). Reef-fish in Bawean Island. Malang: Universitas Brawijaya Press.

Dimara, M.; Hamuna, B.; Kalor, J.D. and Paulangan, Y.P. (2020). Ecological analysis and abundance of coral fish in the waters of Depapre Bay, Jayapura Regency. Journal of Marine Science and Fisheries Papua, 3:8–15. https://doi.org/10.31957/acr.v3i1.1210

Edrus, I.N.; Arief, S. and Iwan, E.S. (2017). Coral reef health in Saleh Bay, Sumbawa: A review of reef bottom substrate aspects and reef fish diversity. Journal Penelitian Perikanan Indonesia, 16:147–161.

English, S.; Wilkinson, C. and Baker, V. (1997). Survey Manual of Tropical Marine Resources, 2nd ed. Townsville: Australian Institute Resources.

Erdana, R.; Pratikto, I. and Suryono, C.A. (2022). Correlation percentage of live coral cover and fish abundance in Koon Marine Protected Areas, Eastern Seram Regency, Maluku Province. J Mar Res, 11(2):145–155. https://doi.org/10.14710/jmr.v11i2.32164

Ernaningsih, E.; Sultan, D.; Asbar, A.; Budimawan, B. and Ruf Kasim, M. (2022). The correlation of coral cover and reef fish density in the biggest archipelagos located in the center of Indonesia. Iran J Ichthyol, 9(2):111–123. https://doi.org/10.22034/iji.v9i2.900/DOR

Fadhillah, C.N.; Rani, C. and Budimawan (2021). Comparison of the effectiveness of using several methods in monitoring coral reef condition.

Faricha, A.; Edrus, I.N.; Utama, R.S.; Dzumalex, A.R.; Salatalohi, A. and Prayuda, B. (2020). The relationship between targeted fishes compositions and live coral cover percentage in Kei Kecil Islands, Maluku. Jurnal Penelitian Perikanan Indonesia, 26(3):147. https://doi.org/10.15578/jppi.26.3.2020.147-157

Fitriadi, C.A.; Dhahiyat, Y.; Purba, N.P.; Harahap, S.A. and Prihadi, D.J. (2017). Coral larvae spreading based on oceanographic condition in Biawak Islands, West Java, Indonesia. Biodiversitas, 18(2):681–688. https://doi.org/10.13057/biodiv/d180234

Ghiffar, M.A.; Irham, A.; Harahap, S.A.; Kurniawaty, N. and Astuty, S. (2017). Relationship between coral reef condition and target coral fish abundance in the waters of Tinabo Besar Island, Taka Bonerate National Park, South Sulawesi. Journal Ilmu Kelautan SPERMONDE, 3(2):17–24. https://doi.org/10.20956/jiks.v3i2.3002

Hadi, T.A.; Abrar, M.; Giyanto; Prayudha, B.; Johan, O.; Budiyanto, A.; Dzumalek, A.R.; Alifatri, L.O.; Sulha, S. and Suharsono (2020). The status of Indonesian coral reefs 2019. Jakarta: Puslit Oseanografi - LIPI.

Hadi, Y.S.; Japa, L. and Zulkifli, L. (2023). Bacillariophyceae diversity as bioindicator of pollution in the coastal waters of Klui Beach, North Lombok. Journal Biologi Tropis, 23(1):86–92. https://doi.org/10.29303/jbt.v23i1.4387

Handoko, D.W. (2008). Coral reef percent cover relationship with coral fish diversity at different depths in the waters of Bawean Island, Gresik Regency, East Java.

Harahap, S.A.; Fadhil, F. and Sunarto, S. (2021). Diseases prevalence of Acropora corals: Study on Semak Daun Island, Seribu Islands, Jakarta. World News of Natural Sciences, 34(1):113–126.

Harsindhi, C.J.; Bengen, D.G.; Zamani, N.P. and Kurniawan, F. (2020). Abundance and spatial distribution of reef fish based on coral lifeforms at Tidung Island, Seribu Islands, Jakarta Bay. AACL Bioflux, 13(2). https://doi.org/10.13057/biodiv/d221033

Harvey, B.J.; Nash, K.L.; Blanchard, J.L. and Edwards, D.P. (2018). Ecosystem-based management of coral reefs under climate change. Ecol Evol, 8(12):6354–6368. https://doi.org/10.1002/ece3.4146

Hasdar, A.W. (2017). Diversity and abundance of coral fish species based on the condition of living coral cover on three islands of the Spermonde Archipelago, South Sulawesi.

Herawati, E.Y.; Maziyyah, S.; Munir, M.; Perdanawati, R.A. and Khasanah, R.I. (2021). Relationship between coral fish community structure and coral cover in Paiton Waters, Probolinggo-East Java, Indonesia. AACL Bioflux, 4(3):1213–1221. http://www.bioflux.com.ro/aacl

Hoey, A.S.; Howells, E.; Johansen, J.L.; Hobbs, J.P.A.; Messmer, V.; McCowan, D.M.; Wilson, S.K. and Pratchett, M.S. (2016). Recent advances in understanding the effects of climate change on coral reefs. Diversity, 8(2). https://doi.org/10.3390/d8020012

Ilyas, I.S.; Astuty, S.; Syawalludin, A.H. and Purba, N.P. (2017). Diversity of target coral fishes associated with diversity of coral growth forms in the core zone of the Anambas Islands Marine Tourism Park. Journal Perikanan dan Kelautan, 8(2).

Irzon, R. (2021). Prospective and environmental problem of tin mining in Karimun Island. Jurnal Lingkungan dan Bencana Geologi, 12(3):181–192. https://doi.org/http://dx.doi.org/10.34126/jlbg.v12i3.367

Irzon, R.; Kurnia, H. and Haryanto, A. (2020). Precision measurement of Nudur tin mining by-products using XRF analysis and economic opportunities of its products. Journal Teknologi Mineral dan Batubara, 16(2):69–79. https://doi.org/10.30556/jtmb.Vol16.No2.2020.1089

Iskandar, R.; Kusuma, Z. and Wiadnya, D.G.R. (2021). Association between coral community coverage with coral reef fish communities at Samber Gelap Island, South

Kalimantan, Indonesia. Egypt J Aquat Biol Fish, 25(3):861–881. https://doi.org/10.21608/ejabf.2021.182968

Joni, Pratomo, A. and Irwan, H. (2017). Growth rate and level of survival coral Acropora formosa results transplantasi depth in different. [Internet]. https://www.researchgate.net/publication/313396342

Kepmen, L.H. (2004). Decree of the Minister of Environment No. 51. 2004 Seawater Quality Standard for Marine Biota. [place unknown].

Labrosse, P.; Kulbicki, M. and Ferraris, J. (2002). Underwater visual fish census surveys: proper use and implementation. [place unknown]: Secretariat of the Pacific Community.

Luthfi, O.M.; Alifia, R.; Rizqia Putri, S.; Bethrix Dasi, F.; Artha Putra, B.; Eka Permana, D.; Pebrizayanti, E.; Zuhal Fikri, M.; Saputro, J.; Ari Setiawan, C. (2017). Monitoring the condition of coral fish using the Reef Check method in the waters of Sempu Strait, South Malang. Journal of Marine and Aquatic Sciences, 3(2):171–179. https://doi.org/10.24843/jmas.2017.v3.i02.171-179

Mujiono, D.I.K. and Oktaviani, J. (2021). The Coral Triangle: benefits, issues and efforts. Journal Dinamika Global, 6(1):1–19. https://doi.org/10.36859/jdg.v6i01.405

Mujiyanto, S.; Sugianti, Y.; Afandy, Y.A.; Rahayu, R.; Budikusuma, R.A.; Nastiti, A.S.; Syam, A.R.; Purnamaningtyas, S.E. (2021). Reef fish community structure in the islands of Paraja Bay, Pandeglang District, Banten, Indonesia. Biodiversitas, 22(10):4402–4413. https://doi.org/10.13057/biodiv/d221033

Munday, P.L.; Jones, G.P. and Caley, M.J. (2001). Interspecific competition and coexistence in a guild of coral-dwelling fishes. Ecology, 82:2177–2189.

Muqsit, A.; Purnama, D. and Ta'alidin, Z. (2016). Community structure of coral reefs in Island Two, Enggano Sub-District, North Bengkulu District. Journal Enggano, 1(1):75–87.

NOAA (2024). NOAA Coral Reef Watch.

Nugraha, W.A.; Mubarak, F.; Husaini, E. and Evendi, H. (2020). The correlation of coral reef cover and rugosity with coral reef fish density in East Java waters. Jurnal Ilmiah Perikanan dan Kelautan, 12(1):131–139. https://doi.org/10.20473/jipk.v12i1.14356

Olán-González, M.; Reyes-Bonilla, H.; Álvarez-Filip, L.; Pérez-España, H. and Olivier, D. (2020). Fish diversity divergence between tropical eastern Pacific and tropical western Atlantic coral reefs. Environ Biol Fishes, 103(11):1323–1341. https://doi.org/10.1007/s10641-020-01026-y

Pearson, E. (1990). Scientific literacy: What is the role of the science teacher? Journal of Negro Education, 59:316–319.

Permana, R.D.; Sunarto, S.; Harahap, S.A.; Riyantini, I. and Ilham, Y. (2021). Potassium cyanide (KCN) content in coral reefs and its effect on the abundance of

indicator-fishes in the Anambas Islands. Journal of Science and Applicative Technology, 5(1):214. https://doi.org/10.35472/jsat.v5i1.381

Pinheiro, H.T.; Martins, A.S. and Joyeux, J.C. (2013). The importance of small-scale environment factors to community structure patterns of tropical rocky reef fish. Journal of the Marine Biological Association of the United Kingdom, 93(5):1175–1185. https://doi.org/10.1017/S0025315412001749

Prato, G.; Thiriet, P.; DI Franco, A. and Francour, P. (2017). Enhancing fish underwater visual census to move forward assessment of fish assemblages: An application in three Mediterranean Marine Protected Areas. PLoS One, 12(6). https://doi.org/10.1371/journal.pone.0178511

Putra, A.G.; Ruswahyuni; Widyorini, N. (2015). Correlations of fish abundance and soft coral cover at different depth in Menjangan Kecil Island National Park of Karimunjawa, Central Java. Diponegero Journal of Aquatic Resources Management, 4. https://doi.org/10.14710/marj.v4i2.8504

Rahman, M.A.; Syamsuddin, M.L.; Agung, M.U.K. and Sunarto (2019). The effect of season on oceanographic conditions in determining skipjack fishing areas (Katsuwonus pelamis) in the southern waters of West Java. Journal Perikanan dan Kelautan, 10(1):92–102.

Ramadhani, R.A.; Damar, A. and Madduppa, D.H. (2015). Management on coral reef ecosystem in the Siantan Tengah District, Anambas Islands. Jurnal Ilmu dan Teknologi Kelautan Tropis, 7(1):173–189. https://doi.org/https://doi.org/10.29244/jitkt.v7i1.9804

Rani, C.; Haris, A.; Yasir, I. and Faizal, A. (2019). Distribution and abundance of coral fish in Liukangloe Island water, Bulukamba District. Jurnal Ilmu dan Teknologi Kelautan Tropis, 11(3):527–540. https://doi.org/10.29244/jitkt.v11i3.20557

Richardson, L.E.; Graham, N.A.J.; Pratchett, M.S. and Hoey, A.S. (2017). Structural complexity mediates functional structure of reef fish assemblages among coral habitats. Environ Biol Fishes, 100(3):193–207. https://doi.org/10.1007/s10641-016-0571-0

Riyantini, I.; Harahap, S.A.; Kostaman, A.N.; Aufaadhiyaa, P.A.; MS, Y.; Zallesa, S.; Faizal, I. (2023). Abundance, diversity and distribution of reef fishes and megabenthos and their relationship with coral reef condition and water quality in Gosong Pramuka, Thousand Islands National Park. Journal Buletin Oseanografi Marina, 12(2):179–191. https://doi.org/10.14710/buloma.v12i2.48793

Rosdianto, L.; Luthfi, O.M.; Khurniawan, S.; Saputra, D.; Maulana, W.A. (2021). Relationship of coral reef cover with reef fish abundance in the waters of Miang Island, Sangkulirang, Kutai East, East Kalimantan. Journal of Environmental Engineering & Sustainable Technology JEEST, 08(01):1–9. https://doi.org/10.21776/ub.jeest.2021.008.01.1

Safitri, W.R. (2016). Pearson correlation analysis in determining the relationship between the incidence of dengue fever and population density in Surabaya City in 2012–2014. Journal Ilmiah Keperawatan, 2.

Setiawan, A.N.; Dhahiyat, Y. and Purba, N.P. (2013). Variation of temperature and chlorophyll-a due to Indonesian throughflow on skipjack distribution in Lombok Strait. Jurnal Ilmu Perikanan, Pesisir, dan Perikanan, 2(2):58–69. http://las.pfeg.noaa.gov/

Sofiyani, I.; Taofiqurrahman, A.; Purba, N.P. and Salahuddin, M. (2012). Analysis of changes in seabed geomorphology due to marine sand mining in the eastern waters of Karium Besar Island, Riau Islands Province. Jurnal Perikanan dan Kelautan, 3(4):327–336.

Souhokka, J. and Patty, S.I. (2013). Monitoring hydrological conditions in relation to coral reef conditions in the waters of Talise Island, North Sulawesi. Journal Ilmiah Platax, 1(3):138–147. https://doi.org/10.35800/jip.1.3.2013.2579

Sudarmaji, S. and Efendy, M. (2021). Closing percentage relationship life of abundance coral reef fish in the waters of Noko Selayar Island Gresik. Juvenil, 2(1):39–46. https://doi.org/10.21107/juvenil.v2i1.9768

Tambunan, F.C.; Munasik and Trianto, A. (2020). Abundance and biomass of reef fish family Scaridae in coral reef ecosystems in Twin Island waters, Karimunjawa, Jepara. J Mar Res, 9(2):159–166. https://doi.org/10.14710/jmr.v9i2.26706

Utama, R.S.; Renyaan, J.; Nurdiansah, D.; Makatipu, P.C.; Suyadi; Hapsari, B.W.; Rahayu, E.M. Della; Sugiharto, A. and Akbar, N. (2022). Diversity of reef fish species in presence of mangrove habitat in Ternate, North Maluku, Indonesia. Biodiversitas, 23(10):5184–5193. https://doi.org/10.13057/biodiv/d231026

Wulandari, P.; Sainal; Cholifatullah, F.; Janwar, Z.; Nasruddin; Setia, T.M.; Soedharma, D.; Praptiwi, R.A.; Sugardjito, J. (2022). The health status of coral reef ecosystem in Taka Bonerate, Kepulauan Selayar Biosphere Reserve, Indonesia. Biodiversitas, 23(2):721–732. https://doi.org/10.13057/biodiv/d230217

Zurba, N. (2019). An introduction to coral reefs as the foundation of our ocean. Unimal Press.