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Contrasting Tide Effect on the Reef Fish Community and Abundance: Study Case on Coral Reef Restoration Site along Pramuka Island

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ABSTRACT

Tides play an important role and host a diverse range of reef fish species. Some coral species and their associated fish have adapted to tidal conditions. It also creates currents that can affect the movement and distribution of reef fish. Kepulauan Seribu is one of the small tropical islands with many coral reefs. In this study, the community and abundance of reef fishes were examined at two different types of tides: high and low tides. Observations were made at a coral reef restoration site on Pramuka Island, the Thousand Islands.Tidal data were obtained from the Geospatial Information Agency (BIG) single daily tidal type (daily ebb tide) for the Pramuka Island. Reef fish abundance was found to be significantly different between high and low tides (ANOVA, $F=14.84$, $P=0.003$). With a range between 25 - 272 individual fish at high tide compared to 108 - 294 individual fish at low tide, it was found that fish were more abundant at low tide. The most species were found at low tide with a total of 65 species, while only 53 species were found at high tide. A total of 14 species were found exclusively at high tide, and 24 species were found exclusively at low tide. SIMPER analysis confirmed that 21 reef fish species contributed highly to the 75.82 differences in reef fish communities between low and high tides, with the five most contributing species being *Pomacentrus alexandreae, Caesio teres*, *Neopomacentrus cyanomos*, *Cheilodipterus quinquelineatus*, and *Caesio cuning*. Our findings generally indicate that, in terms of abundance and species richness, there are more fishes at low tide at the restoration site. This suggests that due to the diversity and abundance of species found under these conditions, tides should be considered when monitoring reef fishes.

INTRODUCTION

Tides play a significant role in shaping coral reef ecosystems by influences on the water circulation, nutrient availability, and habitat structure (i.e., coral reef) **(Eggertsen *et al.*, 2016)**. Tidepools, which exist as isolated ecosystems during low tides, harbor a diverse composition of reef fish species. The abundance and diversity of species within tidepools are influenced by factor, particularly the space of coral reef habitats **(Cox *et al.*,**

2011). Changes in ocean tides can affect species composition and richness within tidepools, with a higher diversity observed at high tides due to larger space of coral reef habitats.

At high tide, the area of the coral reef that is submerged in water is larger, providing more space and resources for fish. Conversely, at low tide, parts of the coral reef may be exposed to the air, limiting the available habitat **(Purnomo, 2021)**. Several types of coral and the fish associated with them have adapted to tidal conditions. Corals that grow in areas exposed to high tides are types that are resistant to exposure to air at low tide. This also indirectly affects the fish community associated with the coral. Tides create currents that can influence the movement and distribution of coral reef fish.

Tidal currents play a role in transporting fish larvae, plankton and nutrients which are important for coral reef ecosystems and the fish that live in them **(Wahyuni, 2019)**. Tidal variations affect water depth, which in turn can affect light penetration and water temperature. These factors are important for coral growth and reef fish activity **(Suryawan, 2020)**.

Since the coral reef ecosystem serves as a home for reef fish, the existence of reef fish and reef coral are undoubtedly tightly intertwined. Reef fish abundance will rise in a direct proportion to the amount of coral reef space **(Nybakken, 1993; Komyakova *et al.*, 2013)**. The Seribu Islands are among the small tropical islands where coral reefs are frequently found serving at least 216 species and 29 families **(Madduppa *et al.*, 2013; Darwin, 2020; Harahap *et al.*, 2021)**. Reef fish abundance and distribution are critical indicators for managing and exploiting these fish ecosystems, which typically support multi-species fisheries, particularly in areas with high fish richness located in the north area of Jakarta.

Some types of reef fish may utilize tidal rhythms for foraging or reproductive activities. For example, some species may be more active at high tide when the foraging area (e.g., coral reef) is larger. Tides can also affect water quality in coral reef ecosystems, such as salinity and sedimentation levels, which in turn can affect the health of corals and the fish communities that depend on them **(Setiawan, 2017)**.

Here, we examined the reef fish community and abundance on two different types of tide, the high tide and the low tide. The observation was conducted at the coral reef restoration site of Pramuka Island located in Seribu Archipelago. By carrying out this study, the information was expected to complement not only to know the contrast between the fish community and abundance at low and high tides but also to inform how to conduct reef fish surveys considering the low and high tides' influence.

MATERIALS AND METHODS

The research was conducted on the Thousand Islands - DKI Jakarta, on Pramuka Island in 2024 (Fig. 1). Observations are made by dividing them based on tidal and low tide conditions, which are also differentiated by month (January and June) and season (wet and dry seasons). The observation location was carried out at a coral reef restoration site on Pramuka Island which is managed by a local community conservation group. This restoration site on Pramuka Island has been carried out consistently over a period of five years since 2020.

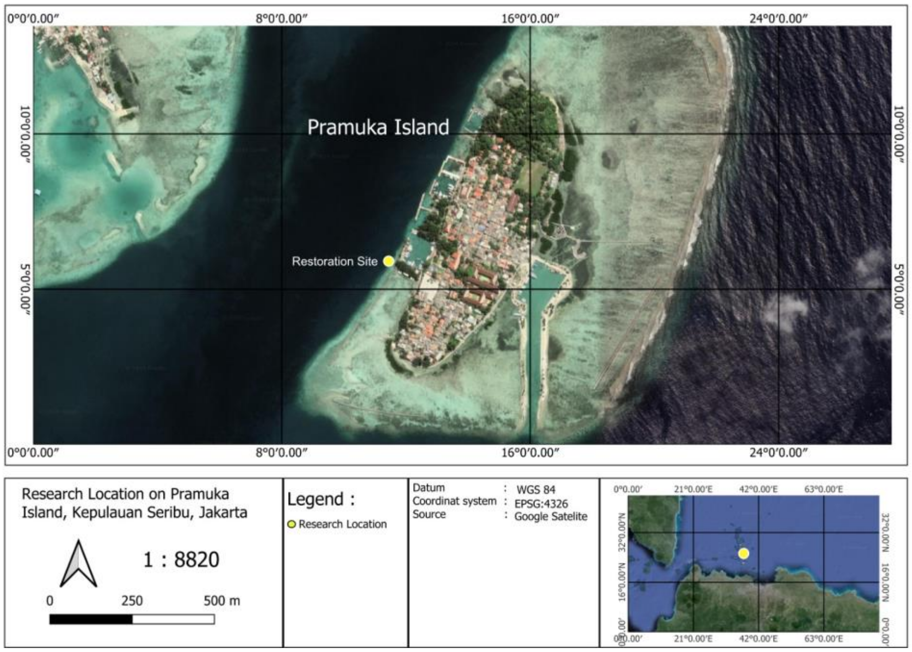

Fig. 1. A. Map showing the observation site located on Pramuka Island, Seribu Archipelago

Sea tidal data collection and visualitation

The tide data used in this study was retrieved from Badan Information Geospasial (BIG) (srgi.big.co.id). The tidal data used is tidal prediction data and measurement data from the BIG field station at Tanjung Priok Station with date range from March 2024 and June 2024.

The method used in processing tidal data is based on the British Admiralty harmonic method for calculating harmonic constants which consist of: mean sea level, amplitude and phase which consists of 9 (nine) main tidal components, namely M2: harmonic constant which is influenced by the position of the moon; S2: Harmonic constant which is influenced by the position of the sun; N2: Harmonic constant which is affected by changes in lunar distance; K2: Harmonic constant which is affected by changes in the distance of the sun; O1: Harmonic constant which is influenced by the declination of the moon; P1: Harmonic constant which is influenced by solar declination; K1: Harmonic constant which is influenced by the declination of the sun and moon; M4: Harmonic constant influenced by the double influence of M2; MS4: Harmonic constant which is influenced by the interaction between M2 and S2.

The data were then analyzed to propose the Admiralty method; whereas, the average sea level was obtained by calculating tidal constants **(Ongkosong, 1989)**. After obtaining the tidal components (e.g., amplitude and phase delay value), data were calcutalted to get information of mean sea level (MSL), lowest low water level (LLWL), and the highest high water level (HHWL) and tidal type.

This tidal constant is used to calculate the average water level and the lowest low water level. The type of tide is determined by the frequency of high and low tides each day. Quantitatively, the tidal type of a body of water can be determined by setting a comparison between the amplitudes of the main single tidal elements and the main double tidal elements using the Formzahl number equation:

$$\text{Formzahl Index (F)} = \frac{A(O1)+A(K1)}{A(M2)+A(S2)}$$

The classification of tides **(Fadilah *et al.*, 2014)** were then determined by following the Formzahl Index:

$F \leq 0.25$	: double daily tides
$0.25 < F \leq 1.5$	: dominant doubles
$1.5 < F \leq 3$	: single dominant
$F > 3$	: single tide

Reef fish data collection

Data collection on reef fish abundance used the Underwater Visual Census (UVC) method **(English *et al.*, 1997)**. This observation used a line transect with a length of 30m and a width of 5m (2.5 meters left and right). The permanent transect line was settled during the data collection to gain presition observation area (Fig. 2), with a total of three replicated 50m transect line and a 5m distanec between each transect.

The abundance and species of reef fish was observed using SCUBA diving. The reef fish species was identified based on the reef fish identification guideline demonstrated by **Allen and Adrim (2003)**.

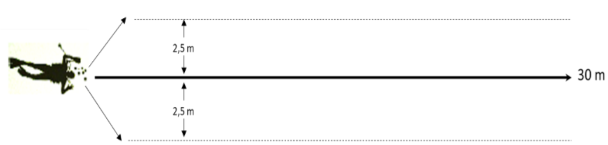

Fig. 2. Reef fish observation method based on Underwater Visual Census (UVC)

Data analysis

The abundance of reef fish was calculated based on total individual per observation area ($250m^2$). The reef fish abundance and communities were then assigned to reveal differentiation between tidal variables (high and low) and two-month variables (January and June). The variety or diversity of species found was measured based on alpha and beta diversity. Alpha diversity is generally described based on species richness, which shows how many species are found in a location. Alpha diversity was used to measure species diversity between variables. Beta diversity is a measure of the extent to which community composition or level of community differentiation changes in various variables. Beta diversity is used in conservation efforts to understand and manage variations in species composition across locations. Alpha (species richness and overlapping taxa at family and species level) and beta (Bray-Curtis similarity) diversity were calculated using Primer v7 software (www.primer-e.com). Statistical tests were applied using ANOVA to see whether there is a significant difference ($P<0.05$) of reef fish abundance between the low and high tide. SIMPER analysis was used to reveal what species make a high contribution of dissimilarities between the low and high tide.

RESULTS

1. Sea tidal profile

The tides in June are realtively lower than in January. The Pramuka Island wave-tide as a prediction wave tide calculated based on the reference wave-tide (Tanjung Priok) is shown in Fig. (3). The results of the Formzhal number calculation are in the range of F > 3, thus the tide can be classified as a single daily type tide (diurnal tide). In single daily tides, there is one high tide and one low tide in a day. Single daily tidal conditions are also strengthened by the larger amplitude values of the single tidal components.

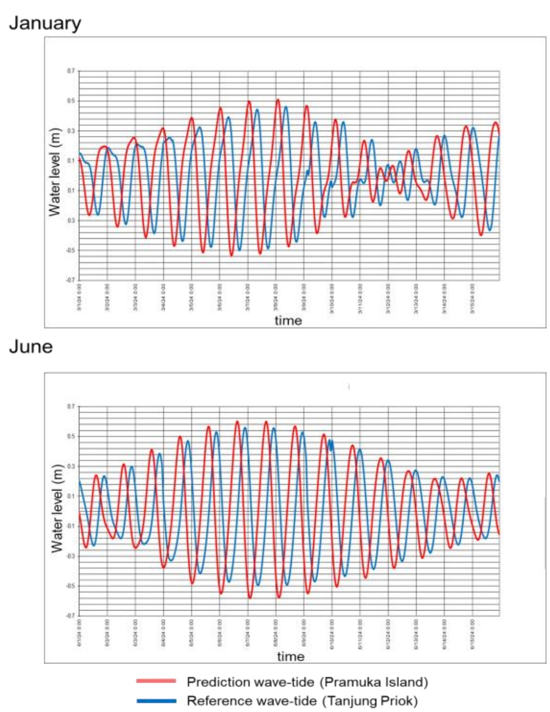

Fig. 3. Reef fish observation method based on Underwater Visual Census (UVC)

The results of calculating the LLWL and the HHWL in the wet season using harmonic components on Pramuka Island are -0.56 and 0.57m, respectively. The LLWL and HHWL calculations in the dry season (June) on Pramuka Island are -0.52 and 0.52m, respectively.

2. Reef fish abudance

Based on reef fish abundance at the family level, we found the highest number of individuals from the Pomacentridae family, except during high tide in June (only 2 individuals were found). The same pattern was also observed from Labridae family that was not oberserved during the high tide in June. In contrast, major fish groups dominate in terms of numbers as found in Pomacentridae, Labridae, and Apogonidae. This family group shows large differences at high and low tide times, both in January and June. Fish in the Caesionidae family have a large abundance, with 63 individuals at low tide and only 9 at high tide (Table 1).

Tabel 1. Detailed abundance information of reef fish family based on sea tidal and month on Pramuka Island

Family	**January**		**June**	
	High tide	**Low tide**	**High tide**	**Low tide**
Apogonidae	6	27	12	21
Aulostomidae	0	0	0	1
Caesionidae	9	25	0	37
Centriscidae	0	2	0	0
Chaetodontidae	3	7	2	9
Ephippidae	0	1	0	11
Holocentridae	1	3	17	0
Labridae	19	19	0	27
Lethrinidae	0	0	0	2
Lutjanidae	0	0	0	1
Monachantidae	1	0	0	0
Muraenidae	1	1	0	0

Nemipteridae	2	5	1	7
Pempheridae	3	5	1	7
Pinguipedidae	1	0	0	0
Pomacanthidae	1	1	0	1
Pomacentridae	58	85	2	120
Scaridae	2	5	0	6
Scorpaenidae	1	0	0	0
Serraridae	1	3	1	1
Siganidae	1	3	1	2
Sphyraenidae	0	0	0	1
Tetraodontidae	0	1	0	1

Reef fish abundance was significantly different between high and low tide (ANOVA, F=14.84, *P*= 0.003). With the range between 25 -272 individuals of fish at high tidal compared to 108 -294 indivudals fo fish at low tidal, we found that fish specimens show more abundance during the low tide (Fig. 3).

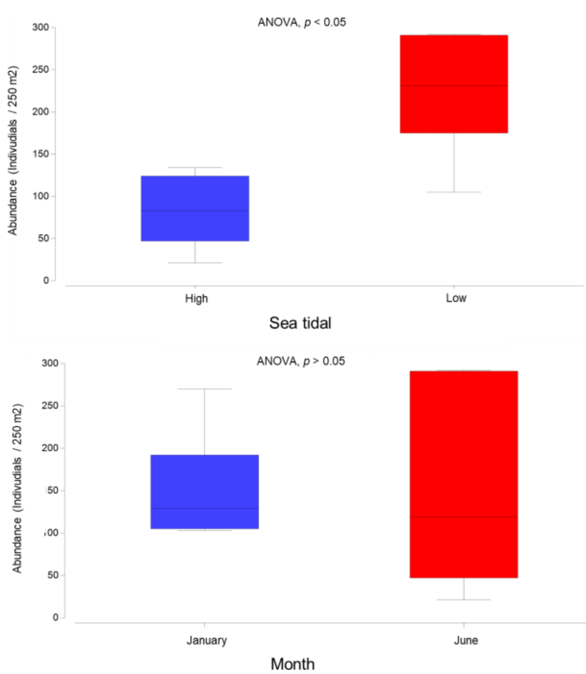

Fig. 3. Comparison of reef fish abudance based on sea tidal and month on Pramuka Island

3. Reef fish community

A total of 77 reef fish species belonging to 23 family were observed during the low and high tide in both months, January and June. Venn diagram (Fig. 4) shows that 21 families were observed at high and low tides, except two familes that were only found during the low tide in January and June. At the species level, the highest number of species was observed during the high tide in January, with a total of 50 species, and 10 species were found exclusively.

The fewest species were found during high tide in June with a total of 16 species, 2 of which were found exclusively. Based on tidal and low tide conditions, the most species were found at low tide with a total of 65 species. At high tide, the total number of species found was 53 species. A total of 14 species were found exclusively at high tide, and 24 species were found exclusively at low tide.

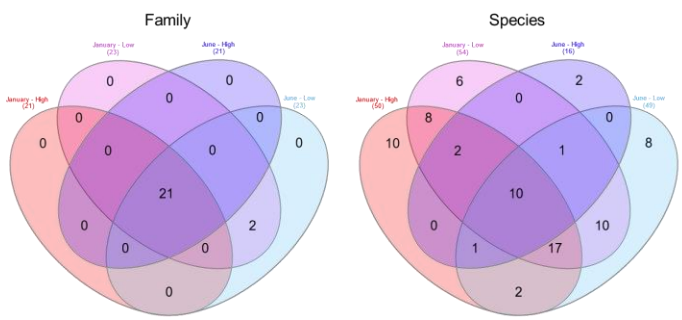

Fig. 4. Species richness and overlapping taxa of reef fish at family and species level based on sea tidal and month on Pramuka Island

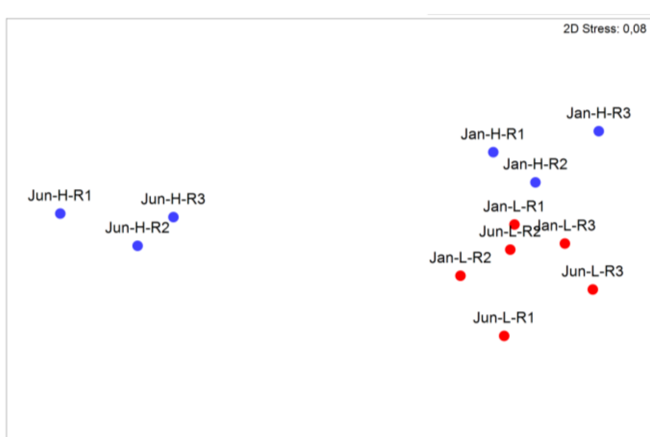

Fig. 5. Beta diversity shown as non-metric multidimensional scales (nMDS) ordination based on Bray-Curtis similarity (●: high tide, ●: low tide)

Beta diversity as shown in Fig. (5), based on non-metrics Multidimensional Scaling (nMDS) using Bray-Curtis similarity, shows the general composition of species at high and low tides, with the stress value of 0.08. Clustering was observed with respect to reef fish species communities at low tide. Meanwhile, there was differentiation of reef fish species communities during the high tide, particularly between January and June.

Species that contributed significantly to differences between fish communities at low and high tides included *Pomacentrus alexandreae*, *Caesio teres*, *Neopomacentrus cyanomos*, *Cheilodipterus quinquelineatus*, *Caesio cuning*, *Amblyglyphidodon curacao*, *Abudefduf sexfasciatus*, *Myripristis murjan*, *Cheilodipterus isostigma*, *Abudefduf vagiensis*, *Chromis analis*, *Amblyglyphidodon leucogaster*, *Chromis ternatensis*, *Chaetodon octofasciatus*, *Halichoeres trispilus*, *Pempheris vanicolensis*, *Platax orbicularis*, *Apogon compressus*, *Thalassoma lunare*, *Pomacentrus smiti*, and *Myripristis pralinia.*

Tabel 2. The largest contribution of reef fish species between categories at high and low tides showing differences based on SIMPER analysis with 75.82 average of dissimilarity

Species	Contribution	Average abundance	
	%	High tide	Low tide
Pomacentrus alexandreae	8.97	12	24.5
Caesio teres	7.25	2.83	18.83
Neopomacentrus cyanomos	7.09	6.83	19.33
Cheilodipterus quinquelineatus	5.84	3	13.83
Caesio cuning	5.17	1.33	12
Amblyglyphidodon curacao	3.34	1.33	8
Abudefduf sexfasciatus	3.12	3	6.5
Myripristis murjan	3.01	6.33	1.5
Cheilodipterus isostigma	2.83	0	7.5
Abudefduf vagiensis	2.83	3.33	6.5
Chromis analis	2.38	0	5.33
Amblyglyphidodon leucogaster	2.26	0	5.5

Chromis ternatensis	2.14	0	4.83
Chaetodon octofasciatus	2.09	2.67	6.67
Halichoeres trispilus	2.08	2	5.33
Pempheris vanicolensis	1.92	1.83	5.67
Platax orbicularis	1.79	0	5
Apogon compressus	1.76	4	1.5
Thalassoma lunare	1.47	1.33	4.17
Pomacentrus smiti	1.47	1.67	2.5
Myripristis pralinia	1.4	2.67	0

DISCUSSION

Variations in the abundance of reef fish species in the coral reef restoration area on Pramuka Island were detcted between high and low tides. Conditions of species abundance during high and low tides in the western season can be demonstrated by several species. *Abudefduf sexfasciatus* and *Abudefduf vagiensis* showed higher abundance at low tide compared to high tide. In contrast, the species *Caesio cuning* and *Caesio teres* are more abundant at high tide. At high tide, the water column around coral reefs becomes wider and brings nutrients to the coral reef area, so that many fish from the Caesionidae family, which eat plankton and tend to cluster in the water column, can be found **(Setiawan *et al*., 2014)**. The abundance of species at high tide and low tide in the east monsoon shows that the abundance of species such as *Amblyglyphidodon curacao* and *Pomacentrus alexandrea* increases significantly at low tide. However, some species such as *Neopomacentrus cyanomos* show high abundance at both high and low tides. The species above belong to the Pomacentridae family, which is a major type of fish that is found in abundant numbers in coral reef ecosystems **(Nurhasinta *et al.*, 2019)**. Tidal conditions appear to significantly influence the abundance of some species.

The average abundance of reef fish families in the coral restoration area on Pramuka Island in the west season and east season above shows that there are 23 fish families identified. The fish with the greatest abundance come from the Pomacentridae family. The Pomacentridae family are generally omnivorous fish and are often found in coral reef areas. Corallivore fish can be found in all locations consisting of the Chaetodontidae family which feeds on coral polyps, especially coral reefs with a branching growth form **(Lenihan *et al.*, 2015; Riansyah *et al.*, 2018)** which is an indicator of coral reef health. This family is more commonly found in the west season than the east season. Based on tidal conditions, the Caesioidae and Apogonidae families are more commonly found at low tide than at high tide. However, the difference in abundance during the west and east seasons is not very significant. Some families are also found only in one season. The Sphyraenidae and Aulostomidae families are found in the east monsoon only. Meanwhile, the Monachantidae and Muraenidae families are only found in the west season. There are also fish that are found only at low tide, namely the Tetraodontidae family.

Species such as *Pomacentrus alexandreae* shows good adaptation to environmental conditions in restoration areas. This species has a high abundance at high tide (24 individuals) and remains significant at low tide (10 individuals) in January. Observed fish in June also shows a very high abundance at low tide with 39 individuals. *Pomacentrus alexanderae* and *Halichoeres prosopeion* are classified into the major group, which plays an essential role in the early stage of coral reef rehabilitation **(Prabowo *et al.*, 2021)**. This fish group is often found swimming in coral reef areas, both in lagoons and outer coral reef areas **(Lieske & Myers, 1994)**.

Species diversity is quite high with a total of 77 species identified. indicating that there is variation in species adaptation to environmental conditions in restoration areas. The abundance of reef fish species on Pramuka Island shows significant variations in species abundance based on season and tidal conditions. The more diverse types of reef fish that are found, the better the ecosystem conditions will be because each type of fish has its own role, including plant eaters, predators, and eroding lime to produce sediment **(Rondonuwu, 2014)**. Reef fish diversity tends to be higher in the west season than the east season. Between high and low tide conditions in the January, there is no consistent difference in terms of diversity. However, in June, diversity tends to be higher at low tide than at high tide. This difference is thought to be caused by the time of data collection when the highest tide occurs at night. The time factor can also be a consideration in collecting data.

The study of sea tides in this research is very important because this parameter has an influence on fish populations. Studies related to the impact of sea tides on fish by **Effendi *et al*. (2016)** on Panggang Island, Semak Daun Island, and Karya Island, all of which are relatively close to Pramuka Island, showed that tides can influence habitat conditions through oceanographic parameters, such as temperature and salinity. Tides can cause the phenomenon of stirring and stratification of water masses which can change the salinity and temperature at each depth. Notably, this affects the condition of the fish population in the research area considering that each fish has its own habitat specifications and tolerance for changes in the habitat environment. Data on fish species in the research area are highly necessary as a complement to studies of changes in fish populations during high tide and low tide conditions, so that it can provide conclusions about how tides affect the condition of fish populations in certain areas.

Sea tides play an important role in the migration or spread of fish larvae in the sea. According to **Prianto *et al.* (2013)**, hydrographic factors such as tidal currents impacts the migratory behavior of fish larvae. Tides are the main environmental factor influencing ichthyoplankton life, triggering water circulation and vertical transport of fish larvae. The speed of tidal currents, especially during high tide, is closely related to the vertical transport of ichthyoplankton **(Boehlert *et al.*, 1985)**. According to **Subiyanto *et al.* (2009)**, differences in the abundance of fish larvae in each location can be caused by differences in water depth due to different tide heights. This affects the currents that carry or move fish larvae and, in turn, affects abundance.

Sea tides can affect the distribution of zooplankton, which is a food source for fish. This can affect fish populations and catches. For example, research by **Yunita and Zainuri (2021)** in Dakiring Village Waters, Socah District, Bangkalan Regency, East Java, found that the serofish catches were influenced by sea tides. Regression data shows that high tides have a positive effect on the number of individuals and species caught. The high abundance of zooplankton during high tide conditions **(Rahayu *et al.*, 2013)** causes the gathering of caught fish in certain areas and depths.

CONCLUSION

Our findings typically show that, in terms of abundance and species richness, there are more fish during low tide in Seribu Islands restoration locations. This reveals that due of the variety and abundance of species found in these conditions, tides must be taken into account when monitoring reef fish.

Acknowledgments

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