BIOTIK
Jurnal Ilmiah Biologi Teknologi dan Kependidikan
P-ISSN: 2337-9812, E-ISSN: 2549-1768
Vol.14, No. 2, 2026. Page 158-171

Coral Fish Ecological Indices and Relationship with Seawater Physical Parameters at Nasi Island

[1] M. Ali Sarong, [2] Wiwit Artika, [3] Ismul Huda, [4]Iswadi, [5]* Nadia Aldyza, and [6] Samsul Kamal

1. Faculty of Teacher Training and Education, Universitas Syiah Kuala, Banda Aceh, Indonesia
2. Faculty of Teacher Training and Education, Universitas Syiah Kuala, Banda Aceh, Indonesia
3. Faculty of Teacher Training and Education, Universitas Syiah Kuala, Banda Aceh, Indonesia
4. Faculty of Teacher Training and Education, Universitas Syiah Kuala, Banda Aceh, Indonesia
5. Faculty of Teacher Training and Education, Universitas Almuslim, Bireuen, Indonesia*
6. Islamic University of Ar-Raniry Banda Aceh, Indonesia

*Correspondence email: nadia.aldyza@gmail.com

Accepted : 18 May 2026
Published: 30 June 2026

Abstrak: Ikan karang merupakan indikator utama kesehatan terumbu dan penyedia jasa ekosistem penting, termasuk menjaga keseimbangan rantai makanan, mengendalikan pertumbuhan alga, dan mendukung perikanan lokal. Pemantauan struktur komunitas ikan karang sangat penting untuk menilai status konservasi terumbu, khususnya di ekosistem Pulau Nasi, Aceh, yang pernah mengalami pemutihan karang dan masih menghadapi tekanan dari aktivitas penangkapan serta pariwisata. Penelitian ini menilai kekayaan jenis, keanekaragaman, dan tingkat kesamaan ikan karang pada tiga stasiun (Deudap, Alue Riyeung, Pasie Janeng) selama Oktober–November 2024 dengan metode *Belt Transect* dan *Underwater Visual Census*. Indeks kekayaan jenis ikan karang di Pulau Nasi tergolong tinggi (7,89–9,65), menandakan ekosistem terumbu masih mampu menyediakan habitat kompleks dan sumber daya yang mendukung banyak spesies. Indeks keanekaragaman 2,98–3,49, kategori sedang hingga tinggi, menunjukkan struktur komunitas relatif seimbang, meski dominasi spesies tertentu dapat memengaruhi fungsi ekosistem. Indeks kesamaan antarstasiun sebesar 52–60% yang dikategorikan tinggi mencerminkan konektivitas ekosistem dan keseragaman kondisi lingkungan antar lokasi. Integrasi ketiga indeks ini menegaskan bahwa terumbu karang Pulau Nasi masih berfungsi sebagai ekosistem resilien, dengan kapasitas mempertahankan keanekaragaman dan stabilitas ekologis meskipun menghadapi tekanan antropogenik dan dampak pemutihan karang. Temuan ini memberikan dasar penting bagi perencanaan konservasi, pengelolaan sumber daya berkelanjutan, dan pengembangan ekowisata di kawasan tersebut.

Kata kunci: Ikan Karang; Keanekaragaman; Indeks Kesamaan; Kekayaan Jenis.

Copyright: © by the authors.
BIOTIK 2026
Open access article under the CC BY-SA Licence

Abstract: Coral reef fishes are primary indicators of reef health and providers of essential ecosystem services, including maintaining food web balance, controlling algal growth, and supporting local fisheries.

Monitoring the structure of coral reef fish communities is crucial for assessing reef conservation status, particularly in the Nasi Island ecosystem, Aceh, which has experienced coral bleaching and continues to face pressures from fishing activities and tourism. This study assessed species richness, diversity, and similarity of coral reef fishes at three stations (Deudap, Alue Riyeung, Pasie Janeng) during October–November 2024 using Belt Transect and Underwater Visual Census methods. The species richness index of coral reef fishes at Nasi Island was high (7.89–9.65), indicating that the reef ecosystem still provides complex habitats and resources that support diverse taxa. Diversity indices ranged from 2.98–3.49, categorized as moderate to high, reflecting relatively balanced community structures, although dominance by certain species may influence ecosystem functioning. Similarity indices between stations ranged from 52–60%, classified as high, suggesting ecological connectivity and uniform environmental conditions across sites. Integration of these indices confirms that the coral reefs of Nasi Island continue to function as resilient ecosystems, with the capacity to maintain biodiversity and ecological stability despite anthropogenic pressures and the impacts of coral bleaching. These findings provide an important foundation for conservation planning, sustainable resource management, and ecotourism development in the region.
Keywords: Coral Reef Fish; Diversity; Similarity Index; Species Richness.

1. Introduction

Nasi Island, located in the Pulo Aceh District of Aceh Besar Regency, lies between the Indian Ocean and the Andaman Sea. This strategic location supports diverse marine ecosystems, including macroalgae, seagrass beds, coral reefs, and coral reef fishes [1]. As one of the important marine habitats in Aceh Province, Nasi Island plays a significant role in maintaining coastal biodiversity and ecosystem functioning.

Coral reef fishes are essential components of reef ecosystems because they contribute to biodiversity while maintaining ecological balance through trophic interactions. As predators, herbivores, and prey, they regulate population dynamics and control algal growth, preventing excessive algal cover that may inhibit coral development [2]. Consequently, coral reef fish diversity and abundance are widely used as indicators of coral reef condition, with population declines often reflecting habitat degradation, pollution, or climate-related disturbances.

The coral reefs of Nasi Island have experienced substantial environmental stress, particularly during the mass bleaching event in 2010, which reduced live coral cover and altered benthic habitats, ultimately affecting coral reef fish communities [3]. Coral bleaching has become one of the most serious consequences of global climate change, causing ecological impacts across multiple biological levels [4]. Bleaching susceptibility is also closely associated with subsequent coral mortality, increasing ecosystem vulnerability [5]. Similar conditions have been reported in nearby Aceh waters, including Weh Island, where coral diseases and bleaching have been documented [6]. Previous studies further demonstrated spatial variation in coral resilience inside and outside marine conservation areas [7], while recent findings linked coral mortality to changes in reef fish abundance, emphasizing the close relationship between coral condition and fish assemblages [8].

Despite these disturbances, coral reef fish communities remain relatively diverse in Nasi Island waters. Surveys in the sublittoral zone of Rinon waters recorded 54 species belonging to 23 families, while Sarong et al. identified 93 species across Deudap, Alue Riyeung, and Pasie Janeng. These findings indicate that reef fish assemblages persist, although variations in species composition among locations suggest the need for further ecological assessment [9].

Ecological indices, including species richness, diversity, and similarity, are widely applied to evaluate coral reef condition and community structure. Species richness represents the number of taxa present, diversity reflects the distribution of individuals among species, and similarity measures compositional overlap among sites. Together, these indices provide valuable information on ecosystem stability, resilience, and ecological connectivity. Coral reef fish assemblages encompass multiple trophic levels and functional groups, making ecological indices effective tools for understanding community dynamics [10]. Their importance for biodiversity monitoring and conservation planning has also been highlighted [11], [12].

In addition to biological interactions, coral reef fish communities are strongly influenced by seawater physical parameters, including temperature, salinity, turbidity, and current velocity. These environmental factors affect species distribution, diversity, and post-disturbance recovery. However, studies examining the relationship between coral reef fish ecological indices and seawater physical parameters in Nasi Island remain limited, particularly following the 2010 bleaching event.

This study aims to analyze the ecological indices of coral reef fishes, including species richness, diversity, and similarity, and to examine their relationship with seawater physical parameters in the waters surrounding Nasi Island. The findings are expected to provide baseline information for coral reef conservation, sustainable fisheries management, and ecotourism development in Aceh while contributing to a better understanding of coral reef resilience under increasing environmental change.

2. Research Method

Time and Sampling Areas

The research was conducted from October to November 2024 in the waters surrounding Nasi Island, Pulo Aceh District, Aceh Besar Regency, Indonesia. The study area was divided into three observation stations. Station I (Deudap Station) is located at 5.6072° N and 95.0132° E; Station II (Alue Riyeung Station) is located at 5.6033° N and 95.1428° E; and Station III (Pasie Janeng Station) is located at 5.6277° N and 95.1319° E. In addition to documenting coral reef fish assemblages, water quality parameters were measured at all observation stations. Parameters measured included temperature, salinity, pH, and dissolved oxygen (DO) using *in situ* methods. By measuring water quality, the study aimed to determine environmental impacts on aquatic ecosystems and provide recommendations for better water resource management in Nasi Island.

DOI: 10.22373/biotik.v12i2.35054
Home page: www.jurnal.ar-raniry.ac.id/index.php/biotik/index

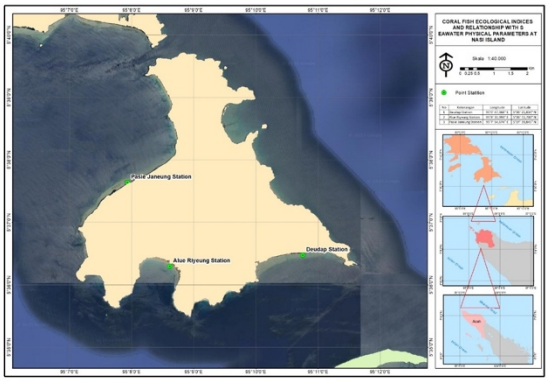


Figure 1. Location site of Nasi Island, Pulo Aceh District.

Data Collection

Coral reef fishes were surveyed using the Belt Transect method with two 50-m transects per station (100 m total) and a 2.5-m belt width on each side. Species were recorded by underwater visual census (UVC) and documented using an underwater camera. Identification followed in situ observations [13].

Data Analysis

Ecological Index

The results of collecting data on coral reef fish found at three observation stations were analyzed using the richness index formula according to Magurran, with the following formulation.

$$R = \frac{(S-1)}{\ln N} \text{..... (1) [14]}$$

Species richness (R) was classified as low (<3.5), moderate (3.5–5.0), and high (>5.5) [15].

The Diversity Index of reef fish is a ecological measure that provides insights into the health and stability of coral reef ecosystems. It quantifies the variety and abundance of species within a particular community. This index was determined using the Shannon Wiener formula (1969).

$$H' = -\sum_{i=1}^{s} Pi \ln Pi \text{ ..... (2) [16], [17]}$$

Diversity index values are categorized into three levels; H' < 1 indicates low diversity, 1 < H' < 3 represents moderate diversity, and H' > 3 signifies

high diversity. Analysis of the level of similarity of coral reef fish species using the Sorensen similarity index formula with the following formulation.

$$IS = \frac{2C}{A+B} x100\% \quad \text{..... (3) [18]}$$

If the IS similarity index is> 50%, then there is a similarity in the area. Similarity values that are getting closer to 100% mean that the similarity of coral fish species in the waters between the three stations is relatively high, while if IS < 50%, then the area has a low level of similarity.

Statistical Analysis

Relationships between physicochemical parameters and coral reef fish richness and diversity were analyzed using Principal Component Analysis (PCA). The analysis was performed in Minitab version 16 to identify patterns among water quality variables, including temperature, salinity, pH, and dissolved oxygen (DO), and coral reef fish ecological indices across sampling stations.

3. Results and Discussion

Coral Reef Fish Composition

A total of 95 coral reef fish species, belonging to 52 genera and 16 families, were recorded from the three sampling stations in the waters of Nasi Island, comprising 472 individuals at Station I, 503 at Station II, and 438 at Station III. Pomacentridae was the most species-rich family with 25 species, followed by Chaetodontidae (19 species) and Acanthuridae (16 species), whereas several families, including Ephippidae, Haemulidae, Pinguipedidae, Siganidae, and Zanclidae, were represented by a single species. The dominance of Pomacentridae reflects its broad ecological tolerance and strong association with coral reef habitats.

The relatively high representation of Chaetodontidae, a family widely recognized as a bioindicator of coral reef condition, suggests that coral habitats in Nasi Island remain sufficiently functional despite environmental

disturbances [7]. This observation is consistent with Warmuth et al. who reported that butterflyfishes and other reef-associated fishes reflect habitat complexity and ecosystem condition, and with Devanya et al., who highlighted the ecological significance of Chaetodontidae in coral reef assessment [19], [20]. The occurrence of herbivorous families such as Scaridae and Siganidae, together with predatory Serranidae, further indicates that essential trophic functions remain intact within the reef ecosystem [21],[22].

Table 1. Coral Reef Fish Found in Nasi Island Waters

Family	Genera	Species
Acanthuridae	4	16
Pomacentridae	8	25
Chaetodontidae	2	19
Labridae	4	5
Scaridae	2	5
Holocentridae	2	4
Pomacanthidae	2	4
Serranidae	2	4
Balistidae	2	2
Mullidae	1	2
Nemipteridae	1	2
Ephippidae	1	1
Haemulidae	1	1
Pinguipedidae	1	1
Siganidae	1	1
Zanclidae	1	1
Total	35	93

Note: A total of 1,413 individuals were recorded from the three sampling stations, comprising 472 individuals at Station I (Deudap), 503 at Station II (Alue Riyeung), and 438 at Station III (Pasie Janeng).

Ecological Indices of Coral Reef Fish

The ecological indices of coral reef fishes at the three sampling stations are presented in Table 2. Species richness ranged from 7.89 to 9.65, whereas the Shannon–Wiener diversity index (H′) ranged from 2.98 to 3.49. Station II (Alue Riyeung) showed the highest richness and diversity, while Station III (Pasie Janeng) recorded the lowest values. Based on the classification of Magurran, all stations were categorized as having high species richness because richness values exceeded 5.5.

The consistently high richness values indicate that coral reef habitats around Nasi Island continue to support diverse fish assemblages, likely due to

the availability of suitable shelter, feeding, and spawning habitats. Food availability and habitat complexity are recognized as important factors influencing reef fish distribution and habitat selection [23], [24]. Differences in diversity among stations suggest local variation in habitat quality and resource availability, with Station II providing more favorable environmental conditions than Station III.

Table 2. Ecological Index of Coral Reef Fish Species in the Waters of Nasi Island

Index	Station I	Station II	Station III
Richness index	8.60	9.65	7.89
Diversity index (H')	3.27	3.49	2.98

Similarity of Coral Reef Fish Communities

The similarity indices of coral reef fish communities are presented in Table 3. The highest similarity occurred between Station II and Station III (60%), whereas the lowest was observed between Station I and Station III (52%), indicating moderate overlap in species composition across the study area.

Variation in similarity among stations is likely associated with differences in habitat characteristics, including substrate composition, depth, and food availability, which influence reef fish assemblages [25],[26],[27]. In addition, environmental conditions such as temperature, salinity, dissolved oxygen, and pH contribute to species distribution and community composition, resulting in differences in similarity among sampling stations [28].

Table 3. Similarity Level of Coral Reef Fish in the Waters of Nasi Island.

Station	I	II	III
I		56	52
II			60
III			

Caption: I (Deudap station), II (Alue Riyeung station), III (Pasie Janeng station)

DOI: 10.22373/biotik.v12i2.35054
Home page: www.jurnal.ar-raniry.ac.id/index.php/biotik/index

Physical–Chemical Characteristics of the Waters

The physical–chemical characteristics of the waters are presented in Table 4. Temperature, salinity, and pH varied among the three sampling stations, whereas dissolved oxygen (DO) remained relatively constant. Overall, the recorded water quality parameters were within ranges suitable for coral reef fish communities [29],[30].

Table 4. Physical-Chemical Factors of Waters

Factors	I (Deudap)	II (Alue Riyeung)	III (Pasie Janeng)
Temperature (°C)	30 ± 0	30.33 ± 0.82	28.5 ± 0.55
Salinity (‰)	30 ± 4.49	33 ± 1.64	34 ± 1.33
DO (mg/L)	7.3 ± 0.52	7.3 ± 0.52	7.3 ± 0.52
pH	6.6 ± 0.10	6.4 ± 0.18	6.3 ± 0.18

Principal Component Analysis (PCA)

The PCA results (Figure 2) showed that the first two principal components explained 100% of the total variance, with F1 and F2 accounting for 72.1% and 27.9%, respectively. Station II was closely associated with species richness, diversity index (H′), temperature, and dissolved oxygen, whereas Station III was more closely related to salinity and pH. Station I occupied an intermediate position, reflecting moderate environmental conditions and ecological indices.

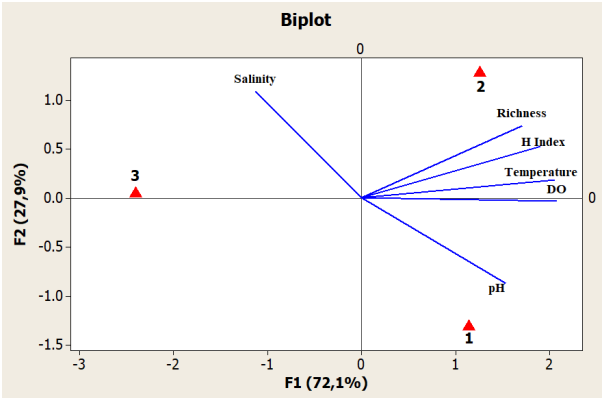


Figure 2. Biplot of station characteristics based on coral reef fish ecological conditions and water parameters.

Discussion

The high species richness and diversity recorded across the three stations indicate that coral reef habitats around Nasi Island remain ecologically functional and capable of supporting diverse reef fish

assemblages. Habitat complexity, ecological connectivity, and resource availability are important factors maintaining reef fish communities [24], [25]. The moderate similarity among stations further suggests that the reef system supports species exchange while retaining local variation in community composition.

The PCA indicated that species richness and diversity were positively associated with temperature and dissolved oxygen, particularly at Station II. Temperature and dissolved oxygen are recognized as key environmental factors affecting fish metabolism, growth, and reproduction [29]. In contrast, Station III was more closely associated with higher salinity and lower temperature, which may explain its comparatively lower diversity. Although the observed salinity remained within the normal range for tropical marine waters [31], salinity variation can influence reef fish physiology, distribution, and community structure through osmotic regulation and energetic demands [32],[33],[34],[35].

The presence of herbivorous and predatory reef fishes further indicates the persistence of essential ecological functions. Herbivorous fishes regulate algal growth and support carbonate cycling, thereby enhancing reef resilience [21]. Overall, these findings demonstrate that integrating ecological indices with environmental variables provides valuable information for evaluating reef condition and supports conservation planning, sustainable fisheries management, and ecotourism development in Nasi Island, consistent with previous findings from Aceh waters [7].

4. Conclusion

Coral reef fish communities in Nasi Island showed high species richness and diversity, indicating relatively good ecological condition. Temperature, dissolved oxygen, and salinity were the principal environmental factors associated with spatial variation in fish community structure. These findings provide baseline ecological information for reef

monitoring and support conservation planning, sustainable fisheries management, and ecotourism development in Aceh.

Conflict of interest

The authors declare no conflict of interest.

Acknowledgements

The authors thank the field survey team for their assistance during data collection and the local community of Nasi Island for their support and cooperation.

5. Reference

[1] A. Setiawan, "Keanekaragaman Hayati Indonesia: Masalah dan Upaya Konservasinya," *Indones. J. Conserv.*, vol. 11, no. 1, pp. 13–21, 2022.

[2] O. M. Luthfi, "Relationship Coral Reef Cover With Reef Fish Abundance In The Waters Of Miang Island, Sangkulirang, Kutai East, East Kalimantan," *J. Enviromental Eng. Sustain. Technol.*, vol. 8, no. 1, pp. 01–09, Sep. 2021, doi: 10.21776/ub.jeest.2021.008.01.1.

[3] K. Jaroensutasinee, S. Somchuea, and M. Jaroensutasinee, "Coral and reef fish community recovery following the 2010 extreme ocean warming event (mass bleaching event) at Thailand," *J. Anim. Behav. Biometeorol.*, vol. 9, no. 1, p. 2104, Sep. 2020, doi: 10.31893/jabb.21004.

[4] R. van Woesik *et al.*, "Coral-bleaching responses to climate change across biological scales," *Glob. Chang. Biol.*, vol. 28, no. 14, pp. 4229–4250, Jul. 2022, doi: 10.1111/gcb.16192.

[5] S. B. Matsuda *et al.*, "Coral Bleaching Susceptibility Is Predictive of Subsequent Mortality Within but Not Between Coral Species," *Front. Ecol. Evol.*, vol. 8, Jun. 2020, doi: 10.3389/fevo.2020.00178.

[6] M. B. Mulya, N. Aldyza, and A. Afkar, "The prevalence of coral health issues in the conservation area of Benteng, Weh Island, Sabang, Indonesia," *AACL Bioflux*, vol. 16, no. 2, pp. 1166–1176, 2023.

[7] N. Aldyza, T. A. Barus, M. B. Mulya, and M. A. Sarong, "Coral resilience inside and outside of Pesisir Timur Pulau Weh conservation zone, Sabang City, Indonesia," *Biodiversitas*, vol. 23, no. 11, pp. 5744–5751, 2022, doi: 10.13057/biodiv/d231126.

[8] N. Aldyza, A. Afkar, M. Hasanah, and C. Roswita, "Coral mortality and fish abundance in the Marine Nature Reserve of the Eastern Coast of Weh Island, Sabang, Aceh," *Arwana J. Ilm. Progr. Stud. Perair.*, vol. 6, no. 2, pp. 131–138, Oct. 2024, doi: 10.51179/jipsbp.v6i2.2861.

[9] M. . Sarong, W. Artika, I. Huda, Iswadi, Rahmah, and S. Fatriana, "Kondisi Habitat dan Tingkat Kerusakan Karang di Perairan Pulau

Nasi Kecamatan Pulau Aceh Kabupaten Aceh Besar Provinsi Aceh," 2024.
[10] I. Bachtiar, T. A. Hadi, K. Karnan, and N. T. Bachtiar, "Other faunas, coral rubbles, and soft coral covers are important predictors of coral reef fish diversity, abundance, and biomass," *Fish. Aquat. Sci.*, vol. 26, no. 4, pp. 268–281, Apr. 2023, doi: 10.47853/FAS.2023.e23.
[11] Y. Gong, J. Zhang, Z. Chen, Y. Cai, and Y. Yang, "Taxonomic Diversity and Interannual Variation of Fish in the Lagoon of Meiji Reef (Mischief Reef), South China Sea," *Biology (Basel).*, vol. 13, no. 9, p. 740, Sep. 2024, doi: 10.3390/biology13090740.
[12] Z. Kang *et al.*, "Species composition and succession of coral reef fishes in Huaguang Reef, Xisha Islands," *Water Biol. Secur.*, vol. 3, no. 3, p. 100273, Jul. 2024, doi: 10.1016/j.watbs.2024.100273.
[13] G. R. Allen, R. Steene, P. Humann, and N. DeLoach, *Reef Fish Identification: Tropical Pacific*. Jacksonville, Florida: New World Publications, Inc., 2003.
[14] A. E. . Magurran, *Measuring biological diversity*. Blackwell Pub., 2004.
[15] I. M. S. Wijana *et al.*, "Indeks Ekologi dan Status Konservasi Jenis Burung (Avifauna) di Desa Gunaksa dan Beberapa Wilayah di Sekitarnya di Kabupaten Klungkung, Bali," *Metamorf. J. Biol. Sci.*, vol. 8, no. 2, p. 238, Sep. 2021, doi: 10.24843/metamorfosa.2021.v08.i02.p07.
[16] Y. Lin, J. Li, Z. Wang, S. Zhang, K. Wang, and X. Li, "A Comparison of Fish Diversity in Rocky Reef Habitats by Multi-Mesh Gillnets and Environmental DNA Metabarcoding," *Front. Ecol. Evol.*, vol. 10, Apr. 2022, doi: 10.3389/fevo.2022.874558.
[17] H. Mulya, Y. Santosa, and I. Hilwan, "Comparison of four species diversity indices in mangrove community," *Biodiversitas J. Biol. Divers.*, vol. 22, no. 9, Aug. 2021, doi: 10.13057/biodiv/d220906.
[18] F. Palendeng, J. D. Kusen, and I. S. Manembu, "Struktur Komunitas Ikan Family Chaetodontidae Sebagai Indikator Kondisi Kesehatan Lingkungan Ekosistem Terumbu Karang Di Zona Tradisional Pulau Bunaken Taman Nasional Bunaken," *J. PESISIR DAN LAUT Trop.*, vol. 9, no. 3, p. 148, Oct. 2021, doi: 10.35800/jplt.9.3.2021.38171.
[19] L. M. Warmuth, S. Kelly, M. A. Samoilys, E. Popova, C. E. I. Head, and M. B. Bonsall, "Environmental change and connectivity drive coral reef fish abundance in the Western Indian Ocean," *ICES J. Mar. Sci.*, vol. 81, no. 9, pp. 1785–1795, Nov. 2024, doi: 10.1093/icesjms/fsae125.
[20] A. Devanya, D. B. Wiyanto, M. Mujiyanto, I. N. Giri Putra, and E. Faiqoh, "Komposisi dan Struktur Komunitas Ikan Kepe-Kepe (Chaetodontidae) di Teluk Paraja, Kabupaten Pandeglang, Banten," *J. Mar. Res. Technol.*, vol. 5, no. 2, p. 99, Aug. 2022, doi: 10.24843/JMRT.2022.v05.i02.p08.
[21] C. T. Perry, M. A. Salter, I. D. Lange, D. P. Kochan, A. R. Harborne, and N. A. J. Graham, "Geo-ecological functions provided by coral reef fishes vary among regions and impact reef carbonate cycling regimes,"

Ecosphere, vol. 13, no. 12, Dec. 2022, doi: 10.1002/ecs2.4288.
[22] R. M. Winter *et al.*, "Grouping groupers in the Mediterranean: Ecological baselines revealed by ancient proteins," *Ecol. Evol.*, vol. 13, no. 10, Oct. 2023, doi: 10.1002/ece3.10625.
[23] R. M. Tharp, N. J. Hostetter, A. B. Paxton, J. C. Taylor, and J. A. Buckel, "Artificial structure selection by economically important reef fishes at North Carolina artificial reefs," *Front. Mar. Sci.*, vol. 11, Apr. 2024, doi: 10.3389/fmars.2024.1373494.
[24] T. Shabi, Y. Ziv, R. Yosef, and N. Shashar, "Deciphering Preferences for Shelter Volume and Distribution by Coral Reef Fish, Using Systematic and Functional Grouping," *J. Mar. Sci. Eng.*, vol. 12, no. 1, p. 186, Jan. 2024, doi: 10.3390/jmse12010186.
[25] M. Samoilys, L. Alvarez-Filip, R. Myers, and P. Chabanet, "Diversity of Coral Reef Fishes in the Western Indian Ocean: Implications for Conservation," *Diversity*, vol. 14, no. 2, p. 102, Jan. 2022, doi: 10.3390/d14020102.
[26] A. E. Hall, D. S. Cameron, and M. J. Kingsford, "Partially protected areas as a management tool on inshore reefs," *Rev. Fish Biol. Fish.*, vol. 31, no. 3, pp. 631–651, Sep. 2021, doi: 10.1007/s11160-021-09654-y.
[27] C. de Alba-Guzmán, A. P. Rodríguez-Troncoso, A. L. Cupul-Magaña, F. A. Rodríguez-Zaragoza, R. A. Cabral-Tena, and J. de Jesús Adolfo Tortolero-Langarica, "Decadal changes in the fish assemblage structure and function within an insular coral community," *Discov. Ecol.*, vol. 1, no. 1, p. 15, Dec. 2025, doi: 10.1007/s44396-025-00015-8.
[28] Q. Zhou *et al.*, "Critical factors driving spatiotemporal variability in the phytoplankton community structure of the coral habitat in Dongshan Bay, China," *Front. Microbiol.*, vol. 15, Feb. 2024, doi: 10.3389/fmicb.2024.1355028.
[29] S. V. Menon *et al.*, "Water physicochemical factors and oxidative stress physiology in fish, a review," *Front. Environ. Sci.*, vol. 11, Sep. 2023, doi: 10.3389/fenvs.2023.1240813.
[30] R. Itsukushima, "Broad-Scale Environmental Factors Determining Fish Species Composition of River Estuaries in the Japanese Archipelago," *Estuaries and Coasts*, vol. 46, no. 7, pp. 1829–1843, Nov. 2023, doi: 10.1007/s12237-023-01248-0.
[31] A. Isdianto *et al.*, "Assessing the relationship between coral cover and coral recruitment in the degraded ecosystems of Sempu Nature Reserve, East Java, Indonesia," *Biodiversitas J. Biol. Divers.*, vol. 25, no. 9, Sep. 2024, doi: 10.13057/biodiv/d250929.
[32] A. Armanto, Y. A. Nurrahman, and S. Helena, "Kelimpahan dan Keanekaragaman Ikan Karang di Perairan Selatan Pulau Kabung Kabupaten Bengkayang, Kalimantan Barat," *J. Laut Khatulistiwa*, vol. 5, no. 2, p. 62, Aug. 2022, doi: 10.26418/lkuntan.v5i2.54096.
[33] F. Tony, S. SOEMARNO, D. G. R. WIADNYA, and L. HAKIM, "Diversity of reef fish in Halang Melingkau Island, South Kalimantan, Indonesia," *Biodiversitas J. Biol. Divers.*, vol. 21, no. 10, Sep. 2020, doi: 10.13057/biodiv/d211046.

[34] W. A. Nugraha, F. Mubarak, E. Husaini, and H. Evendi, "The Correlation of Coral Reef Cover and Rugosity with Coral Reef Fish Density in East Java Waters," *J. Ilm. Perikan. dan Kelaut.*, vol. 12, no. 1, pp. 131–139, Mar. 2020, doi: 10.20473/jipk.v12i1.14356.

[35] A. K. Putri *et al.*, "Komposisi, Keanekaragaman, dan Relung Ekologi Ikan di Plawangan Timur Segara Anakan, Jawa Tengah," *J. Mar. Aquat. Sci.*, vol. 9, no. 2, p. 241, Mar. 2024, doi: 10.24843/jmas.2023.v09.i02.p09.