BIODIVERSITAS
Volume 26, Number 1, January 2025
Pages: 153-165

ISSN: 1412-033X
E-ISSN: 2085-4722
DOI: 10.13057/biodiv/d260117

Fish diversity and associated physicochemical conditions in seaweed farming areas in Bone Gulf Waters, South Sulawesi, Indonesia

FIJWAL PATANGNGARI[1,2], MUSBIR MUSBIR[2,♥], NAJAMUDDIN[2]

[1]Doctoral Program in Fisheries Science, Faculty of Marine Science and Fisheries, Universitas Hasanuddin. Jl. Perintis Kemerdekaan Km. 10, Makassar 90245, South Sulawesi, Indonesia. Tel./fax.: +62-411-586025, ♥email: musbir_unhas@yahoo.co.id; musbir@unhas.ac.id

[2]Faculty of Marine Science and Fisheries, Universitas Hasanuddin. Jl. Perintis kemerdekaan Km. 10, Makassar 90245, South Sulawesi, Indonesia

Manuscript received: 26 November 2024. Revision accepted: 10 January 2025.

Abstract. *Patangngari F, Musbir M, Najamuddin. 2025. Fish diversity and associated physicochemical conditions in seaweed farming areas in Bone Gulf Waters, South Sulawesi, Indonesia. Biodiversitas 26: 153-165.* The waters of Bone Gulf, located on the coast of Bone District, possess a longstanding legacy of fishing gear, specifically small fishing gear with a mesh size of 15 mm, which is in use today because of the substantial population along the coast. Seaweed farming regions have increasingly become alternatives to fishing zones. This research examines fish diversity and environmental factors in seaweed cultivation zones. Fish were obtained from fishermen utilizing fishing gear in seaweed regions, specifically around the Cape (ST 1), the middle (ST 2), and a distant estuary (ST 3) in Bone waters, from February to August 2024. 2375 fish specimens were gathered, encompassing 67 species from 40 families. Increased diversity was noted in species count (15-46), the species diversity index (2.48-3.18), the evenness index (0.832-0.910), the species richness index (2.64-6.96), and the species dominance index (0.057-0.096). The five most frequently captured species were *Chanos chanos, Leiognathus fasciatus, Siganus guttatus, Terapon jarbua, Crenimugil seheli*, and *Lates calcarifer,* together with *Oreochromis mossambicus*, classified as Vulnerable (VU), and *Himantura uarnak,* classified as Endangered (EN). Principal Component Analysis (PCA) shows that current velocity and depth are the main factors significantly associated with fish stocks. Furthermore, the phosphate, turbidity, nitrate, salinity, temperature, pH, and dissolved oxygen metrics exhibited no significant impact across the three sites. Future research should focus on long-term monitoring of fish population dynamics, investigating the effects of seaweed farming on fish community structure, and formulating sustainable management practices that engage local communities to preserve and enhance aquatic ecosystems and ensure long-term ecosystem health.

Keywords: Conservation, fish diversity, physicochemical, Principal Component Analysis (PCA), seaweed farming

INTRODUCTION

Indonesia ranks second as the world's largest fish producer, with a fish catch of 78.8 million tons (Ramadhani 2023). Fish (vertebrates) are the primary source for more than a billion people worldwide. Fish diversity is estimated to reach 32,500 species (Pir et al. 2019). In Indonesia itself, there are more than 8,500 species of fish classified based on habitat characteristics, such as salty, brackish, and freshwater waters (Gani et al. 2021; Hasan et al. 2023). The ocean and its marine resources are also a significant protein, food, and livelihood source (Gibson et al. 2020). Fisheries contributed 2.8% of Indonesia's gross domestic product (GDP) in 2020 (BPS 2021). The ocean contributes to livelihoods, food and nutrition security, and well-being for many households in Indonesia, including disadvantaged families. With proper and sustainable management, Indonesia's fisheries can improve economic, social, and environmental performance. But along with this development, capture fisheries production in Bone District increased significantly, with the number of sero vessels increasing from 400 units in 2019 to 446 units in 2020 (DKP 2019-2023; Patangngari et al. 2022). Relevant authorities must focus on recording fish caught using traditional methods, as many fishing boats dock in village rivers, indicating that exploitation and erosion of fish resources in coastal areas are dynamic and highly productive (Hasan and Islam 2020; Ndobe et al. 2022; Patangngari and Musbir 2024). Many marine animal species coexist and thrive here, creating a structured community (de Azevedo et al. 2023; Anderson et al. 2024; Chabrerie and Arenas 2024). It is feared that there will be overexploitation of fish in coastal areas (Hasan et al. 2021; Derbal et al. 2022).

Bone Gulf, with its calm currents, is an ideal habitat for fish. The calm currents have made fish traps made from bamboo the leading choice of fishermen for hundreds of years (Sudirman 2018). Along with the times, the fishing gear has now switched to more modern materials such as trolley nets, waring, and tasting with sizes of 5 mm, 15 mm, and 25 mm. These traps are generally installed on the coast, especially in mangrove areas and river estuaries (Hasbi et al. 2020; Hewindati et al. 2023) and seagrass beds (Irawan et al. 2018). The abundance of seaweed in the coastal area is an option for installing this static fishing gear. Previously, tests had been carried out on bubu fishing gear (Musbir et al. 2020; Musbir and Bohari 2021) operated in Bulukumba Sea Flores' waters. Seaweed can produce ecological benefits for fish by adding structural complexity and possible food sources in coastal areas (Hehre and Meeuwig 2015) and becoming a refuge from prey. Seaweed is one of the famous marine aquaculture commodities in South Sulawesi, Indonesia (Geo et al. 2020). The primary method used to cultivate seaweed is the longline method that floats on the water's surface (Nurdin et al. 2023; Pessarrodona et al. 2024), thus allowing many disturbances, such as being eaten by fish. Seaweed production positively correlates with the catch of siganid fish cultivated in coastal areas (Hehre and Meeuwig 2016). Fish such as siganid from the Siganidae family or herbivorous fish, which feed on seaweed thallus, which reduces their daily growth rate and productivity, so installing trap fishing gear such as bubu and sero is one alternative that can be tried by paying attention to the location in the area.

Previous research on fishing gear in Bone Gulf has focused chiefly on the level of fishing gear productivity and effectiveness (Yonvitner et al. 2020; Ardiansyah 2022) and the composition of fishermen's catches (Patangngari et al. 2022). These studies recorded the number and type of fish caught. However, few examined the biodiversity of the catch or how the composition of the species is affected by physicochemical environmental conditions such as temperature, current velocity, salinity depth, DO, pH, brightness, nitrate, phosphate, and turbidity in the water, and especially in seaweed cultivation areas.

Information on biodiversity patterns is essential for ecosystem function and conservation (Hasan et al. 2023; Isdianto et al. 2024). The distribution and habitat of species in different regions are shaped by evolutionary processes and biogeographical, climatic, and ecological processes (Bannar-Martin et al. 2018; Hasan et al. 2023) Although this fishing gear has long been used and is an integral part of the Bone Gulf fisheries economy, there is no structured reporting system related to biodiversity in coastal areas, especially what fish are caught in seaweed areas. Monitoring changes in fish populations and ecosystem conditions is very important to ensure the sustainability of fishery resources in the future. It is the first step in proving the existence of this document (Hehre and Meeuwig 2015). The study investigated fish biodiversity, local physicochemical environmental conditions, and species status according to the International Union for Conservation of Nature (IUCN). This research will substantially enhance initiatives to conserve and manage fisheries resources and provide data essential for protecting ecosystem-critical coastal biodiversity. Findings from this study can guide adaptive and sustainable fisheries management decisions and policies in areas within the waters of Bone Gulf to contribute to global efforts to address the challenges posed by climate change and its impacts on marine ecosystems.

MATERIALS AND METHODS

Study areas

The sero fishery population in Bone District is the largest in Indonesia, making it an ideal research site. One innovative aspect of this study was trap technology deployed in seaweed areas, which serve as a food source and a refuge for fish (Rasnijal et al. 2021). The research area comprises three stations, as shown in (Figure 1), with coordinates listed in (Table 1): Tanjung Pallette and Cempalagi in Bone District, South Sulawesi, Indonesia. The rocky mountains encircle the area, and the Bone Gulf seagrass region was selected based on geographic criteria. These sites were chosen to examine the impact of varying ecological conditions on fish catch and physicochemical conditions, which are indicators of the health and stability of aquatic ecosystems.

Table 1. Sampling locations in seaweed farming areas in the waters of Bone District, Bone Gulf, South Sulawesi, Indonesia

Sampling point	Latitude	Longitude
Stasiun seaweed farming 1	4°27'46.80"S	120°23'30.49"E
Stasiun seaweed farming 2	4°27'16.78"S	120°23'4.97"E
Stasiun seaweed farming 3	4°26'38.24"S	120°22'49.82"E

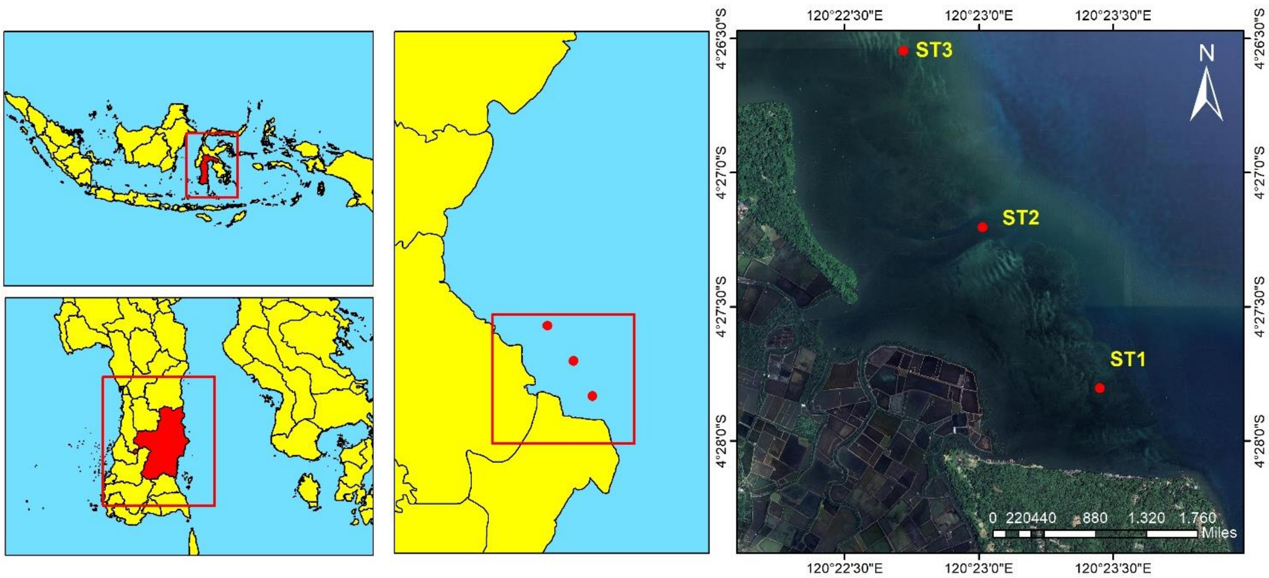

Figure 1. The location of Bone Gulft shows biodiversity sampling sites in Bone District, South Sulawesi, Indonesia

Environmental parameters

For this study, to analyze the water quality in estuaries and canals, various physicochemical parameters were measured in situ using the multi-parameter water quality monitor tester mater AZ 86031 system, i.e., temperature, pH, salinity, and DO, and using such disks for brightness and Water samples from each location were collected in 1,000 mL sampling bottles and immediately stored in ice boxes for nitrate physicochemical analysis, phosphate, turbidity. Furthermore, the water samples were transported to the Faculty of Marine Sciences and Fisheries Laboratory, Hasanuddin University, Makassar, so that inorganic nutrients in the water samples could be analyzed by following the standard protocol given by Parsons et al. (1984).

Data collection procedure

Data collecting

This study will collect fish catch data from three distinct stations chosen using purposive sampling, randomly selecting the fish traps deployed in the seaweed region's right, center, and left margins. The data collection process entails identifying fish by species within the sample basket. Fish identification follows the methodologies established by Saanin (1995) and Carpenter and Niem (2001), utilizing FishBase and SeaLifeBase to ascertain the International Union for Conservation of Nature (IUCN) status of both fish and non-fish. Subsequently, the number of fish per species and measurements of total fish length and crab length are recorded, employing a ruler with an accuracy of 0.1 cm. Sampling occurred four times monthly, from February to August.

Sampling method

The sampling method used is a passive trap type (sero) with an appropriate mesh size to avoid size errors in fishing. Sampling was carried out monthly for seven months to capture species variation under different ecological conditions on the fish diversity index. The caught fish are separated into species groups for identification.

Data analysis

Relative Abundance (RA) was expressed in the number of one group of organisms in a community. Relative abundance was calculated through the formula put forward by Krebs (2014) that was:

$$RA = \frac{n_i}{N} \times 100\%$$

Where,
RA : Relative abundance (%)
n_i : Number of individuals in the 'each' species
N : Total number of individuals

Analysis of the diversity of the fish community. The species diversity index was calculated using the Shannon-Wiener diversity index, with the formula as follows;

$$H' = \Sigma - (P_i * \ln P_i)$$
$$i = 1$$

Where,
H′ : The value of the Shannon-Wiener diversity index
S : The number of species
P_i : The proportion of the total sample belonging to the species
ln P_i : The natural logarithm of P_i

The evenness index, with values indicating the distribution of fish species at each site, was calculated using Pielou's index, with the formula as follows:

$$J = H'/H' \max$$

Where,
E : The values of the evenness index (range 0-1); the closer to 1, the higher the evenness
H' : The Shannon-Wiener index
S : The total number of species
H'_{max} : The maximum species diversity

The species richness index was calculated using the Margaletf index, with the formula as follows:

$$R = (S-1)/Ln (n)$$

Where,
R : Richness index
n : The total number of fish found
S : The total number of fish species found

The Dominance Index (D) measures the extent to which one group of biota dominates other groups. Significant dominance can cause communities to become unstable and depressed (Odum and Barret 2005). The Simpson dominance index is used to determine if there is a dominant species.

$$1 - D = 1 - \sum_{i=1}^{n}\left(\frac{n_i}{N}\right)^2$$

Where,
D : Simpson dominance index
n_i : Number of individuals in the 'each' species
N : Total number of individuals

Presence Frequency (PF) is a value that states the number of species present in a predetermined research station. FK could be calculated using the following formula (Krebs 2014):

PF 0-25% : Hardly ever-present
PF 25-50% : Seldom present
PF 50-75% : Sometimes present
PF 75-100% : Generally present

Data on fish populations, species, Shannon diversity index (H'), species richness (S), and uniformity index (E) were collected monthly from February to August at fish trap sites within seaweed cultivation zones in the waters of Bone Gulf. The critical component analysis (PCA) technique is used to examine high-dimensional data, which proves helpful in extracting structures from complex data sets (Harefa and Zhou 2022). The analysis was carried out using the EXCELSTAT software to determine the parameters that most significantly affect species diversity.

RESULT AND DISCUSSION

Species distribution and fish community structure

A total of 2375 individuals were arrested, and 40 families were found in area 3 of the seaweed area, if described for ST 1 consisting of 15 species and 198 individuals, ST2 consisting of 45 species and 554 individuals, and ST3 consisting of 47 species of 1623 individuals, more details can be seen in (Table 2) and (Figure 2).

Conservation of fish resources is essential in sustainable fisheries management, and biodiversity reporting is critical in evaluating organisms in the future (Butorac et al. 2020; Couture et al. 2024). The results of this study provide significant insights for the planning and development of protected areas. Fish biodiversity research helps use this insight to design more efficient conservation policies emphasizing the most diverse and representative taxa to protect fish diversity in coastal areas or rivers globally (Zhou and Li 2024).

Species composition and IUCN red list status

The conservation status of 67 species of fish at 3 stations can be seen in (Figure 4), showing that there is one endangered fish species with endangered (EN), namely Honeycomb stingray (*Himantura uarnak*), and one species is vulnerable to extinction vulnerable (VU) the mozamican tilapia fish (*Oreochromis mossambicus*). The number of species that are still in the status of not yet evaluated (NE) consists of 2 species, namely, Spottail needlefish *(S. strongylura*), Fourfinger threadfin (*E. tetradactylum*). The status of fish that are not in the official category or have not been included in the IUCN (NR) not read conservation assesment list are 6 species, namely cardinalfish (*Apogon* sp.), Dusky batfish (*P. pinnatus*), Deep-bodied mojarra (*G. erythrourus*), Black-barred halbeak (*H. far*), False Trevally (*L. lactarius*), Eubleekeria jonesi (*E. jonesi*). Some species have minimal data distribution Data Deficient (DD), so there is no information available to classify the risk of certain species, there are 2 species, namely Hawaiian ladyfish (*E. hawaiensis*), Indo-Pacific tarpon (*M. cyprinoides*) and the last is the most dominant species that is still in good health and has a stable population (LC) there are 55 species 5 of them such as the Spottail needlefish (*S. strongylura*), Indian threadfish (*A. indicus*), Duskyshoulder trevally (*C. humerosus*), Golden Trevally (*G. speciosus*) and White trevally (*C. tille*). Many studies have assessed fish resources in coastal areas in Indonesia, such as in Wakatobi (Fekri et al. 2024), India (Majhi et al. 2024), and Thailand. However, especially in the waters of Bone Gulf, reports of fish diversity are rarely found in international journals, considering that Bone Gulf is an area with a reasonably large catch using traditional trap fishing equipment in Indonesia.

Applying and reviewing IUCN (International Union for Conservation of Nature) criteria is one of the long-term strategies for systematically assessing the level of ecosystem threats. This is essential for understanding the level of ecosystem degradation and the risk of extinction due to human activities, all of which aim to identify changes in the landscape scale in guiding land-use planning and strategic conservation at the local and national levels (Noh et al. 2020). This status is among the most important and globally recognized conservation assessment systems (Faruque and Matsuda 2021; Zhao et al. 2022; Tuncharoen et al. 2024). In the context of fish resources, this status plays a crucial role because it can guide scientists, fisheries managers, and policymakers in decision-making related to the conservation and management of fish stocks in various ecosystems. This assessment is critical given that human activities, including overfishing, pollution, climate change, and loss of natural habitats, often threaten fish resources in different regions. By understanding the conservation status of specific fish species based on IUCN assessments, governments, and conservation organizations can formulate policies to prevent further population declines, such as establishing no-fishing zones or limiting catch quotas (Horodysky et al. 2016).

Seaweed diversity in the area of the installation of fish traps

The following types of seaweed are cultivated in the area where the fish traps are installed, as seen in (Figure 3). A. *Kappaphycus alvarezii*, B. *Euchema cottoni*, C. *Kappaphycus striatum*, fish favor all of these species as a source of supplementary food and shelter from prey (Hehre and Meeuwig 2015; Rasnijal et al. 2021). The availability of seaweed on the coast of Bone Gulf is varied; some locations are not available throughout the year due to the influence of river estuaries that bring fresh water when it rains, and they are available all year round because it is located in the Tanjung area and there are only small rivers. Based on data from the Central Statistics Agency of South Sulawesi Province, 2024, the eighth largest grass cultivation production volume in Bone District with a production volume of 200,901 tons/year (BPS 2024). This potential shows that the availability of seaweed resources in Bone District is very abundant and is also one of the targets of herbivorous fish in seaweed cultivation areas.

Indeks of diversity, evenness, species richness index, and dominance

The balance of fish community structure and the richness of fish species in aquatic ecosystems can be seen through the index of diversity, equity, and dominance (Roy et al. 2022). The diversity index is a value that can show the balance of diversity by dividing the number of individuals of each type (Desrita et al. 2022; Roy et al. 2022). The analysis results of the diversity, uniformity, and dominance index are presented in (Figure 5). The Shannon-Wiener diversity index (H') shows that ST 1 has a value of 2.48, ST 2 is 3.17, and ST 3 is 3.18. Based on the index criteria, the species diversity in ST 2 and ST 3 is classified as high, while ST 1 is classified as low. The uniformity index (E) in ST 1 is 0.91, ST 2 is 0.834, and ST 3 is 0.832. This uniformity value indicates that although the populations at all three classified stations have small uniformity, a value close to 1 indicates a relatively even distribution between species, with almost the same number of individuals per species. The dominance index (C) shows that ST 1 has a value of 0.096, ST 2 is 0.059, and ST 3 is 0.057. Based on the dominance index criterion (C<0.5), it can be concluded that there are no dominant species in all three stations. Thus, the three stations are not ecosystems dominated by a specific species. The species richness index shows that ST 2 has the highest value, 6.96, followed by ST 3 with a value of 6.08, and ST 1 with a value of 2.64. The index provides a comprehensive overview of the balance and health of ecosystems at each research station. This analysis shows ST 2 and ST 3 have better diversity and species richness than ST 1. This can be used as a basis for sustainable ecosystem management (Rohim et al. 2024; Siriwattanarat et al. 2024; Tuncharoen et al. 2024). To achieve sustainable management, it is essential to maintain high diversity and good evenness and prevent excessive dominance by only one or a few species (Derebe et al. 2023). Data from these three indices can guide fisheries management and aquatic ecosystem conservation policies (Dulvy et al. 2021).

Table 2. A collection of fish communities caught in seaweed cultivation areas

Family/Scientific name	Common name	Local name	I	II	III	F	RA (%)	IUCN (Red list)
Apogonidae								
Apogon sp.	Cardinalfish	Petek	0	2	0	2	0.08%	NR
Belonidae								
Strongylura leiura	Banded needlefish	Julung-julung	0	8	0	8	0.34%	NE
Strongylura strongylura	Spottail needlefish	Julung julung	0	0	51	51	2.15%	LC
Carangidae								
Alectis indicus	Indian threadfish	Talang-talang	0	0	6	6	0.25%	LC
Carangoides humerosus	Duskyshoulder trevally	Talang kecil	0	46	39	85	3.58%	LC
Platycaranx malabaricus	Malabar trevaly	Talang-talang	0	0	4	4	0.17%	LC
Gnathanodon speciosus	Golden trevally	Kuwe mas	0	0	16	16	0.67%	LC
Caranx tille	White trevally	Kuwe hitam	0	25	34	59	2.48%	LC
Scomberoides iysan	Doublespotted queenfish	Talang talang	0	0	38	38	1.60%	LC
Selar crumenophthalmus	Purse-eyed scad	Belitong	0	0	16	16	0.67%	LC
Selaroides leptolepis	Yellowstripe scad	Selar kuning	0	35	0	35	1.47%	LC
Chanidae								
Chanos chanos	Milk fish	Bandeng	18	75	187	280	11.79%	LC
Cichlidae								
Oreochromis mossambicus	Mozambique tilapia	Mujair	8	16	18	42	1.77%	VU
Clupeidae								
Amblygaster leiogaster	Smoothbelly sardinella	Tembang	0	4	0	4	0.17%	LC
Dasyatidae								
Himantura uarnak	Honeycomb stingray	Pari macan	0	1	2	3	0.13%	EN
Drepaneidae								
Drepane punctata	Spotted sicklefish	Cermin	5	5	5	15	0.63%	LC
Ephippidae								
Platax pinnatus	Dusky batfish	Kepe-kepe	27	9	1	37	1.56%	NR
Elopidae								
Elops hawaiensis	Hawaiian ladyfish	Bulan-bulan	0	0	27	27	1.14%	DD
Gerreidae								
Gerres erythrourus	Deep-bodied mojarra	Kakap pasir	0	2	0	2	0.08%	NR
Gobiidae								
Bathygobius fuscus	Dusky frillgoby	Goby	0	0	22	22	0.93%	LC
Hemiramphidae								
Hemiramphus far	Black-barred halbeak	Julung-julung	0	0	10	10	0.42%	NR
Holocentridae								
Sargocentron diadema	Crown squirrelfish	Sersan	0	0	2	2	0.08%	LC
Labridae								
Labotes surinamensis	Tripletail	Kerondong	0	10	2	12	0.51%	LC
Lactariidae								
Lactarius lactarius	False trevally	Lembu-lembu	0	0	11	11	0.46%	NR
Latidae								
Lates calcarifer	Barramundi	Kakap putih	4	7	113	124	5.22%	LC
Leiognathidae								
Eubleekeria jonesi	Eubleekeria jonesi	Peperek	0	0	13	13	0.55%	NR
Leiognathus fasciatus	Striped ponyfish	Peperek	29	0	149	178	7.49%	LC
Loliginidae								
Loligo sp.	Longfin squit	Cumi	0	18	47	65	2.74%	LC

Lutjanidae								
Lutjanus adetii	Yellow-banded snapper	Kakap merah	0	3	0	3	0.13%	LC
Lutjanus fulvus	Blacktail snapper	Kakap coklat	11	1	53	65	2.74%	LC
Lutjanus fulviflamma	Dorry snapper	Kakap bintik	0	16	0	16	0.67%	LC
Lutjanus peru	Pacific red snapper	Kakap merah	0	1	0	1	0.04%	LC
Lethrinidae								
Lethrinus harak	Thumbprint emperor	Lencam	0	0	6	6	0.25%	LC
Matutidae								
Matuta victor	Common moon crab	Kepiting bulan	10	0	20	30	1.26%	LC
Megalopidae								
Megalops cyprinoides	Indo-Pacific tarpon	Bulan-bulan	5	2	53	60	2.53%	DD
Mugilidae								
Crinimugil seheli	Bluespot mullet	Belanak	27	9	120	156	6.57%	LC
Moolgarda pedaraki	Longfin mullet	Belanak	4	0	0	4	0.17%	LC
Mullidae								
Upeneus sulphureus	Sunrise Goatfish	Beloso	0	5	10	15	0.63%	LC
Upeneus vittatus	Stripped goat fish	Belooso loreng	0	11	5	16	0.67%	LC
Penaeidae								
Litopenaeus vannamei	Whiteleg shrimp	Udang vaname	0	53	0	53	2.23%	LC
Panaeus monodon	Giant tiger prawn	Udang windu	0	1	13	14	0.59%	LC
Paneus marguensis	Bananan prawan	Udang putih	0	43	0	43	1.81%	LC
Plotosidae								
Plototus lineatus	Striped eel catfish	Sembilang	0	0	1	1	0.04%	LC
Polynemidae								
Eleutheronema tetradactylum	Fourfinger threadfin	Senangin	0	1	4	5	0.21%	NE
Portunidae								
Thalamita crenata	Wide front swimingcrab	Kepiting mangrove	0	6	35	41	1.73%	LC
Portunus pelagicus	Blue swimming crab	Rajungan	0	14	15	29	1.22%	LC
Portunus sanguinolentus	Threespot swimming crab	Rajungan	0	0	63	63	2.65%	LC
Scylla serrata	Mud Crab	Kepiting bakau	0	10	10	20	0.84%	LC
Scaridae								
Scarus quoyi	Quoy's parrotfish	Najong	0	1	0	1	0.04%	LC
Scatophagidae								
Scatophagus argus	Spotted scat	Kiper	0	0	3	3	0.13%	LC
Scombridae								
Rastrelliger kanagurta	Indian mackerel	Kembung	0	2	33	35	1.47%	LC
Sciaenidae								
Johnius borneensis	Sharpnose hammer croaker	Kurisi	0	0	6	6	0.25%	LC
Serranidae								
Epinephelus quoyanus	Longfin grouper	Kerapu	0	3	0	3	0.13%	LC
Epinephelus merra	Honeycomb grouper	Kerapu	0	5	0	5	0.21%	LC
Epinephelus polyphekadion	Camouflage grouper	Kerapu	0	3	0	3	0.13%	LC
Siganidae								
Siganus canaliculatus	White-spotted spinefoot	Baronang susu	0	31	0	31	1.31%	LC
Siganus guttatus	Orange-spotted spinefoot	Baronang totol	10	25	135	170	7.16%	LC
Siganus javus	Streaked spinefoot	Baronang angin	0	5	68	73	3.07%	LC
Siganus puellus	Masked spinefoot	Baronang biru	0	2	0	2	0.08%	LC
Siganus spinus	Little spinefoot	Baronang duri	18	0	2	20	0.84%	LC
Siganus vermiculatus	Vermiculated spinefoot	Baronang bulu ayam	0	4	0	4	0.17%	LC
Siganus virgatus	Barhead spinefoot	Baronang garis garis	0	1	0	1	0.04%	LC
Sillaginidae								
Sillago sihama	Silver sillago	Kurisi	0	8	0	8	0.34%	LC
Sphyraenidae								
Sphyraena barracuda	Great barracuda	Barakuda	3	22	18	43	1.81%	LC
Tetraodontidae								
Arothron manilensis	Narrow-lined puffer	Buntal	0	1	0	1	0.04%	LC
Terapontidae								
Terapon jarbua	Jarbua terapon	Kerong-kerong	19	2	136	157	6.61%	LC
Toxotidae								
Toxotes jaculatrix	Banded archerfish	Pemanah	0	0	1	1	0.04%	LC

Notes: F: Frequency; RA (%): Relatif Abundance; LC: Least Concern; NR: Not Recognized; DD: Data Deficient; NE: Not Evaluated; VU: Vulnerable; EN: Endangered


A
B
C
D
E
F
G
H
I
J
K
L
M
N
O
P
Q
R
S
T
U
V
W
X
Y
Z
AA
AB
AC
AD
AE
AF
AG
AH
AI
AJ
AK
AL
AM
AN
AO
AP
AQ
AR
AS
AT
AU
AV
AW
AX
AY
AZ
BA
BB
BC
BD
BE
BF
BG
BH
BI
BJ
BK
BL
BM
BN
BO

Figure 2. Documentation of fish specimens found in the seaweed farming area capture area. A. *Apogon* sp.; B. *Strongylura leiura*; C. *Strongylura strongylura*; D. *Alectis indica*; E. *Carangoides humerosus*; F. *Platycaranx malabaricus*; G. *Gnathanodon speciosus*; H. *Caranx tille*; I. *Scomberoides iysan*; J. *Selar crumenophthalmus*; K. *Selaroides leptolepis*; L. *Chanos chanos*; M. *Oreochromis mossambicus*; N. *Amblygaster leiogaster*; O. *Himantura uarnak*; P. *Drepane punctata*; Q. *Platax pinnatus*; R. *Elops hawaiensis*; S. *Gerres erythrourus*; T. *Bathygobius fuscus*; U. *Hemiramphus far*; V. *Sargocentron diadema*; W. *Labotes surinamensis*; X. *Lactarius lactarius*; Y. *Lates calcarifer*; Z. *Eubleekeria jonesi*; AA. *Leiognathus fasciata*; AB. *Loligo* sp.; AC. *Lutjanus adetii*; AD. *Lutjanus fulvus*; AE. *Lutjanus fulviflamma*; AF. *Lutjanus peru*; AG. *Lethrinus harak*; AH. *Matuta victor*; AI. *Megalops cyprinoides*; AJ. *Crinimugil seheli*; AK. *Moolgarda pedaraki*; AL. *Upeneus sulphureus*; AM. *Upeneus vittatus*; AN. *Litopenaeus vannamei*; AO. *Panaeus monodon*; AP. *Paneus marguensis*; AQ. *Plototus lineatus*; AR. *Eleutheronema tetradactylum*; AS. *Thalamita crenata*; AT. *Portunus pelagicus*; AU. *Portunus sanguinolentus*; AV. *Scylla serrata*; AW. *Scarus quoyi*; AX. *Scatophagus argus*; AY. *Rastrelliger kanagurta*; AZ. *Johnius borneensis*; BA. *Epinephelus quoyanus*; BB. *Epinephelus merra*; BC. *Epinephelus polyphekadion*; BD. *Siganus canaliculatus*; BE. *Siganus guttatus*; BF. *Siganus javus*; BG *Siganus puellus*; BH. *Siganus spinus*; BI. *Siganus vermiculatus*; BJ. *Siganus virgatus*; BK. *Sillago sihama*; BL. *Sphyraena barracuda*; BM. *Arothron manilensis*; BN. *Terapon jarbua*; BO. *Toxotes jaculatrix*

Figure 3. Types of seaweed installed in the area of installation of trap fishing gear. A. *Kappaphycus alvarezii*; B. *Euchema cottoni*; C. *Kappaphycus striatum*

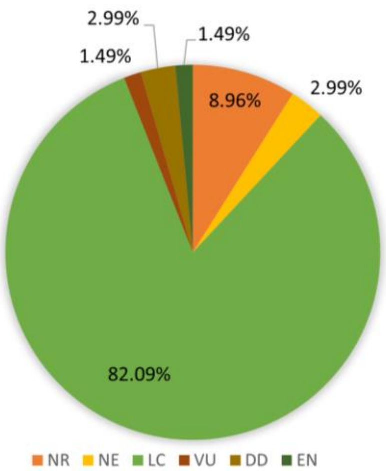

Figure 4. IUCN status information (International Union for Conservation of Nature). NR: Not Recognized; NE: Not Evaluated; LC: Least Concern; VU: Vulnerable; DD: Data Deficient; EN: Endangered

Relationship of fish assemblage and environmental parameters

The physicochemical parameters of the water measured in place during the study in the coastal area of Bone Gulf can be seen in (Table 4). The temperature range is (28.48-29.90°C), the current speed range (0.19-0.21 m/s), the DO range (6.51-7.82 mg/L), the pH range (7.87-8.26), the salinity range (30.95-32.52 ppt), transparency range (0.93-1.2 m), nitrate range (0.72-0.85 mg/L), turbidity range (0.71-2.16 NTU), and phosphate range (0.018-0.036 mg/L) and depth (4-4.5 meter). In addition, the environmental condition that has a high range is transparency, where the conditions in the area near the cape have a lower level of brightness due to the influence of water coming from the river and also because of the waves that always hit the rocks so that there is water that stirs in the cape area which causes a very low brightness value and a very high turbidity value (Li et al. 2020), When compared to areas in seaweed cultivation areas with very high brightness levels and very low turbidity levels, the water in these areas looks blue and clear (DeAngelo et al. 2023; Zhang et al. 2024).

Analysis of the relationship between the physicochemical aquatic environment and fish caught in the aquatic environment is one of the determining factors for the existence of fish stocks. Based on PCA (Principal Component Analysis) analysis, biplot graphs were obtained to see the proximity between various environmental factors, fish collections at each station, and characterization factors of each research station. Correlations between various factors are determined from angles (<900), while not correlated with shape angles (>900) or using information from correlation matrices obtained from the XLSTAT program (Figure 6) shows that each environmental factor and station is spread across the quadrant and correlates with the environmental parameters and the research station (Parenden et al. 2023; Siriwattanarat et al. 2024). ST 1 has parameters such as turbidity, phosphate, and transparency, which correlate with the location of the installation of fish traps in front of large rivers, so these parameters are characteristic of this station. Meanwhile, ST 2 has parameters in the form of current speed, number of species, and depth caused by its location far from the cape, being in deep waters, and being exposed to large waves. Unlike ST 1 and ST 2, ST 3 has no special characterizing parameters. The location is near Tanjung Pallette, with a substrate in the form of rocks and no river flowing around it. In addition, nitrate, salinity, temperature, pH, and DO parameters did not significantly affect the three research stations. This is suspected to be due to the distance between the trap installation sites only a few kilometres, making it impossible to have specific characteristics. Each station's low and high characteristics can be seen from the location of the parameter in the positive (+) or negative (-) quadrant.

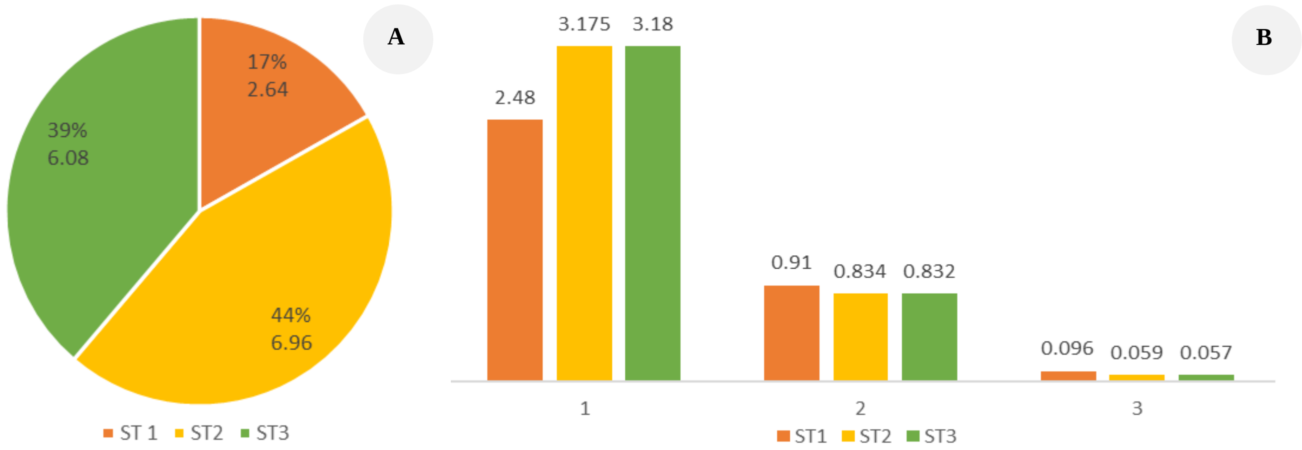

Figure 5. A. Percentage of total fish species richness in seaweed farming catchment areas on the coast of Bone Gulf; B. Index of Diversity (H'), Evenness (H), dominant index analysis (C) of fish species assemblage from seaweed cultivation fishing area in coastal Bone Gul, South Sulawesi, Indonesia

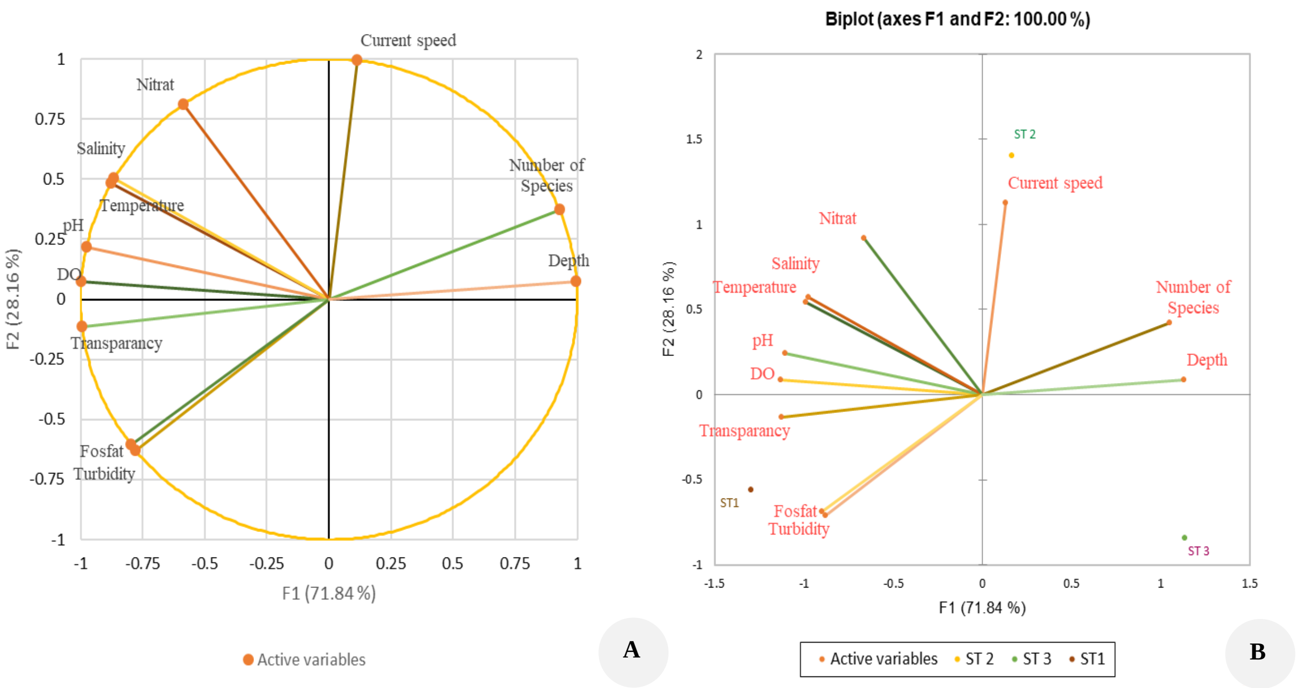

Figure 6. Biplot graph of PCA analysis. A. Environmental factors and number of species; B. Environmental factors, fishing trap installation stations at the research site

Table 4. Ranges of physiochemical parameters measured at the Bone Gulf, South Sulawesi, Indonesia

Environmental parameters	Seaweed farming areas		
	ST1	ST2	ST3
Temperature (°C)	28.48±0.22	29.69±0.83	29.90±0.89
Current speed (m/s)	0.19±0.08	0.20±0.07	0.19±0.08
DO (Dissolved Oxygen) (mg/L)	6.51±0.22	7.12±0.73	7.82±0.68
pH	7.87±0.23	8.10±0.31	8.26±0.24
Salinity (ppt)	30.95±4.52	32.33±4.09	32.52±3.40
Transparency (m)	0.93±0.33	1.01±0.47	1.2±0.66
Nitrate (mg/L)	0.72±0.17	0.85±0.04	0.81±0.19
Turbidity (NTU)	1.11±0.50	0.71±0.53	2.16±1.35
Phosphate (mg/L)	0.02±0.002	0.018±0.003	0.026±0.010
Depth (m)	4±0	4.5±0	4.5±0

The waters of Bone Gulf, especially the research location located between a rocky mountain and a seaweed cultivation zone, are unique because it is a place to install fishing gear and seaweed cultivation for many small fishermen. The headland area where the fishing gear is installed is bordered by large and small rivers, significantly affecting the fish population. In previous studies, all stations following the cape, referred to as characteristic factors, were identified based on phosphate and turbidity levels. The correlation between phosphate and turbidity in water primarily concerns the role of phosphate as a nutrient for microbes, mainly algae (Inyang and Wang 2020). When phosphate concentrations increase, this can encourage excess algae growth, especially in freshwater ecosystems. This process, known as eutrophication, results in an explosion of algae populations, which then die and decompose, releasing organic particles that can increase the turbidity of the water (Beau and Brischoux 2021). High phosphate levels generally come from agricultural and urban wastes entering the aquatic system, causing visible water quality degradation from increased turbidity and decreased dissolved oxygen levels that are important for aquatic life (Baustian et al. 2018).

The main determinant is the speed of the current. This factor has a great impact on the success of fishermen's fishing in seaweed areas because the intensity of the ocean currents determines the number of fish caught in the water. Research shows that current velocity in coastal areas is correlated with fish catch, largely due to its influence on fish distribution and foraging habitats. In coastal areas, current fluctuations significantly contribute to the enrichment of the environment with nutrients essential for small fish and plankton, thus increasing predatory fish populations. In the coastal regions of Ghana, climate change and fluctuations in ocean currents are substantially impacting fish catches by altering the distribution and availability of fish stocks (Ankrah et al. 2024). Medium current velocities often facilitate optimal fish aggregation and foraging conditions, while overly strong currents can hinder fish mobility and reduce fishing efficiency (Cianchetti-Benedetti et al. 2018). Research in coastal areas of Australia shows that currents affect fish populations around coral reefs, as species adapt to certain current levels for optimal swimming efficiency and avoid predators. Steady currents in these regions typically increase fish populations and fishing efforts (Farias et al. 2018). The position of the installer greatly affects the catch in the coastal area, not only because of the current, but also because of other factors such as depth. This study shows that the optimal catch is in a river area, where currents have a positive correlation with the number of catches. In addition, based on the PCA analysis above, depth is also an important factor that affects the results of the catch. Depth as a significant covariate in some models that analyze fish populations. This suggests that different species of fish respond to the inward differently. Another thing is that depth also plays a role in the distribution of species, biomass, and the existence of fish stocks as a whole in coastal ecosystems (Bergström et al. 2019).

Top six catch distributions

The size distribution of dominant fish species shows a standard shape for Milkfish (*C. chanos*) Common ponyfish (*L. equula*), Orange-spotted spinefoot (*S. guttatus*), Jarbua terapon (*T. jarbua*), and Barramundi (*L. calcarifer*) can be seen in Figure 5.

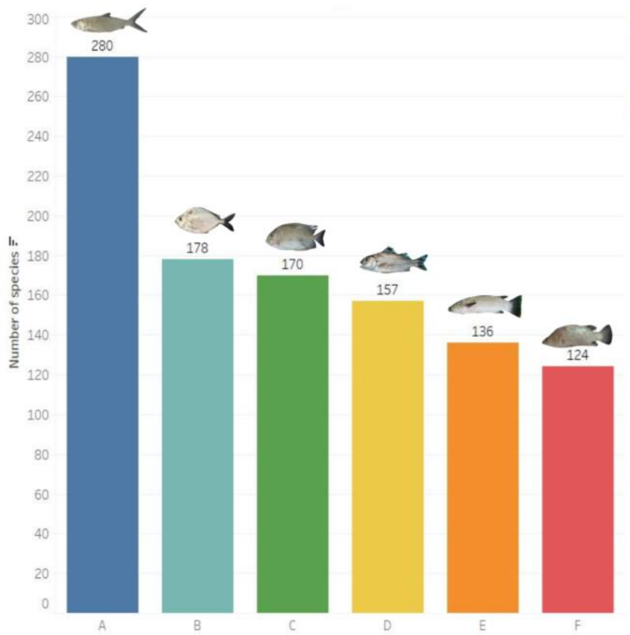

Figure 5. Six dominant fish species in Bone Gulf. A. *Chanos chanos*; B. *Leiognathus fasciatus*; C. *Siganus guttatus*; D. *Terapon jarbua*; E. *Crinimugil seheli*; F. *Lates calcarifer*

This study concludes the importance of understanding fish diversity in seaweed farming areas. This knowledge is critical to ecosystem function and conservation efforts, as it provides important data to protect coastal diversity that is crucial to the ecosystem. The study identified current speed and depth as the main significant physicochemical factors affecting trap catch rates. Other factors such as phosphate, turbidity, nitrate, salinity, temperature, pH, and dissolved oxygen were found to have no significant impact at these three sites. 2455 individuals of 76 species and 39 families were found, with the most frequently caught species including *C. chanos, L. fasciatus, S. guttatus, T. jarbua*, and *C. seheli*. Notably, *O. mossambicus* and *H. uarnak* are classified as vulnerable and endangered according to IUCN data, respectively. These findings are intended to guide adaptive and sustainable fisheries management decisions. This is crucial to contribute to global efforts to address the challenges of climate change and its impacts on marine ecosystems. In the future, there should be a focus on long-term monitoring of fish population dynamics and the effects of seaweed farming on fish community structure. The study also recommends formulating sustainable management practices involving local communities to conserve and enhance aquatic ecosystems and ensure long-term health.

ACKNOWLEDGEMENTS

This work was supported by the Ministry of Research, Technology and Higher Education of Indonesia through “Basic Research” with contract number 050/E5/PG.02.00.PL/2024 and "PMDSU” with contract number 02035/UN4.22.2/PT.01.03/2024.

REFERENCES

Ahmad F, Sharma S, Sharma G. 2019. Diversity and abundance of fishes inhabiting the western region of Narmada River Madhya Pradesh India. Intl J Life Sci 9: 11-17.

Anderson KJ, Kominoski JS, Choi CJ, Stingl U. 2024. Functional effects of subsidies and stressors on benthic microbial communities along freshwater to marine gradients. Ecology 10: e4427. DOI: 10.1002/ecy.4427.

Ankrah J, Monteiro A, Madureira H. 2024. Climate variability, coastal livelihoods, and the influence of ocean change on fish catch in the coastal savannah zone of Ghana. Water 16: 1201. DOI: 10.3390/w16091201.

Ardiansyah, Arwin. 2024. Analisis produktivitas dan komposisi hasil tangkapan alat tangkap sero di Pulau Karampuang Mamuju Sulawesi Barat. Jurnal Sains dan Teknologi Perikanan 2: 70-78. [Indonesian]

Bannar-Martin KH, Kremer CT, Ernest SKM, Leibold MA, Auge H, Chase J, Declerck SAJ, Eisenhauer N, Harpole S, Hillebrand H, Isbell F, Koffel T, Larsen S, Narwani A, Petermann JS, Roscher C, Cabral JS, Supp SR. 2018. Integrating community assembly and biodiversity to better understand ecosystem function: The community assembly and the functioning of ecosystems (CAFE) approach. Ecol Lett 21: 167-180. DOI: 10.1111/ele.12895.

Baustian JJ, Kowalski KP, Czayka A. 2018. Using turbidity measurements to estimate total phosphorus and sediment flux in a Great Lakes coastal wetland. Wetlands 38: 1059-1065. DOI: 10.1007/s13157-018-1044-3.

Beau F, Brischoux F. 2021. Fish-farming bolsters algal fouling and negatively affects condition and reproduction in European pond turtles (*Emys orbicularis*). Sci Nat 108 (1): 12. DOI: 10.1007/s00114-021-01723-3.

Bergström L, Karlsson M, Bergström U, Pihl L, Kraufvelin P. 2019. Relative impacts of fishing and eutrophication on coastal fish assessed by comparing a no-take area with an environmental gradient. Ambio 48: 565-579. DOI: 10.1007/s13280-018-1133-9.

BPS [Badan Pusat Statistik]. 2024. Provinsi Sulawesi Selatan dalam Angka. BPS Provinsi Sulawesi Selatan, South Sulawesi. [Indonesia]

BPS [Badan Pusat Statistik]. 2021. Statistical Yearbook of Indonesia. BPS Statistics, Jakarta. [Indonesian]

Butorac D, Santos P, Phouvin P, Guegan F. 2020. Freshwater fisheries conservation can increase biodiversity. PLos One 15: e0233775. DOI: 10.1371/journal.pone.0233775.

Carpenter KE, Niem VH. 2001. The Living Marine Resources of the Western Central Pacific. Bony Fishes Part 4 (Labridae to Latimeriidae), Estuarine Crocodiles, Sea Turtles, Sea Snakes, and Marine Mammals. FAO of The United Nations, Rome.

Chabrerie A, Arenas F. 2024. What if the upwelling weakens? Effects of rising temperature and nutrient depletion on coastal assemblages. Oecologia 205: 365-381. DOI: 10.1007/s00442-024-05571-6.

Couture JL, Bradley D, Halpern BS, Gaines SD. 2024. Could fish aggregation at ocean aquaculture augment wild populations and local fisheries?. PLos One 19: e0298464. DOI: 10.1371/journal.pone.0298464.

De Azevedo J, Franco JN, Vale CG, Lemos MFL, Arenas F. 2023. Rapid tropicalization evidence of subtidal seaweed assemblages along a coastal transitional zone. Sci Rep 13: 11720. DOI: 10.1038/s41598-023-38514-x.

De Angelo J, Saenz BT, Arzeno-Soltero IB, Frieder CA, Long MC, Hamman J, Davis KA, Davis SJ. 2023. Economic and biophysical limits to seaweed farming for climate change mitigation. Nat Plants 9: 45-57. DOI: 10.1038/s41477-022-01305-9.

Derbal F, Hamdi S, Rouag-Laouira L, Chaoui L, Kara MH. 2022. Diet of the European eel *Anguilla anguilla* (Linnaeus, 1758) in two transitional waters of Southwestern Mediterranean. Cybium 46: 3-11. DOI: 10.26028/cybium/2022-461-001.

Derebe Y, Derebe B, Kassaye M, Gibru A. 2023. Species diversity, relative abundance, and distribution of avifauna in different habitats within Lewi Mountain, Awi zone, Ethiopia. Heliyon 9: e17127. DOI: 10.1016/j.heliyon.2023.e17127.

Desrita R, Rambey R, Muhtadi A, Onrizal O, Manurung VR, Hasibuan JS, Tamba IS. 2022. Biodiversity of nekton in the Barumun Watershed, South Labuhanbatu District, North Sumatra, Indonesia. Biodiversitas 23 (5): 2426-2432. DOI: 10.13057/biodiv/d230521.

DKP [Dinas Perikanan Bone]. 2019-2023. Laporan Tahunan Dinas Perikanan. Dinas Perikanan, Kabupaten Bone, Sulawesi Selatan. [Indonesian]

Dulvy NK, Pacoureau N, Rigby CL, Pollom RA, Jabado RW, Ebert DA, Finucci B, Pollock CM, Cheok J, Derrick DH, Herman KB, Sherman CS, VanderWright WJ, Lawson JM, Walls RHL, Carlson JK, Charvet P, Bineesh KK, Fernando D, Simpfendorfer CA. 2021. Overfishing drives over one-third of all sharks and rays toward a global extinction crisis. Curr Biol 31: 4773-4787. DOI: 10.1016/j.cub.2021.08.062.

Farias EGG, Preichardt PR, Dantas DV. 2018. Influence of fishing activity over the marine debris composition close to coastal jetty. Environ Sci Pollut Res 25 (16): 16246-16253. DOI: 10.1007/s11356-018-2012-4.

Faruque H, Matsuda H. 2021. Assessing the vulnerability of bycatch species from Hilsa gillnet fishing using productivity susceptibility analysis: Insights from Bangladesh. Fish Res 234: 105808. DOI: 10.1016/j.fishres.2020.105808.

Fekri L, Analuddin K, Adimu HE, Chadijah A. 2024. Species composition and size distribution of fishes in mangrove ecosystems in Kendari and Staring Bays, Southeast Sulawesi, Indonesia. Biodiversitas 25 (10): 3683-3692. DOI: 10.13057/biodiv/d251030.

Gani A, Nurjirana, Bakri AA, Adriany DT, Wuniarto E, Khartiono LD, Satria DH, Hasan V, Herjayanto M, Burhanuddin AI, Moore AM, Kobayashi H. 2021. First record of *Stiphodon annieae* Keith & Hadiaty, 2015 (*Teleostei, Oxudercidae*) from Sulawesi Island, Indonesia. Check List 17: 261-267. DOI: 10.15560/17.1.261.

Geo LO, Halim, Ariani WOR. 2020. Farming production analysis of seaweed and farmer’s perception towards climate change effect in Southeast Sulawesi, Indonesia. Pak J Biol Sci 23: 1004-1009. DOI: 10.3923/pjbs.2020.1004.1009.

Gibson E, Stacey N, Sunderland TCH, Adhuri DS. 2020. Dietary diversity and fish consumption of mothers and their children in fisher households in Komodo District, Eastern Indonesia. PLos One 15: e0230777. DOI: 10.1371/journal.pone.0230777.

Harefa E, Zhou W. 2022. Laser-Induced breakdown spectroscopy combined with nonlinear manifold learning for improvement aluminum alloy classification accuracy. Sensors 22: 3129. DOI: 10.3390/s22093129.

Hasan V, Andraini NE, Isroni W, Sari LA, Nafisyah AL, Dewi NN, Putri DNA, Prasasti TAB, Ramadhani AA, Daniel K, South J, Vieira LO, Ottoni FP, Maftuch, Faqih AR, Wirabuana PYAP, Tamam MB, Valen FS. 2023. Fish diversity of the Bengawan Solo River estuary, East Java, Indonesia. Biodiversitas 24 (4): 2207-2216. DOI: 10.13057/biodiv/d240433.

Hasan V, Gausmann P, Ottoni FP. 2021. First scientific observation of the threatened speartooth shark *Glyphis gylphis* (Muller & Henle, 1839) (Carcharhiniformes: Carcharhinidae) in Indonesia. Cybium 45 (4): 321-324. DOI: 10.26028/cybium/2021-454-010.

Hasan V, Islam I 2020. First inland record of Bull shark *Carcharhinus leucas* (Müller & Henle, 1839) (Carcharhiniformes: Carcharhinidae) in Celebes, Indonesia. Ecol Montenegrina 38: 12-17. DOI: 10.37828/EM.2020.38.3.

Hasbi IM, Jumrawati J, Angraeni H. 2020. Study of the behavior of fish caught with sero through echofishfinder observation in the waters of the Tallo River Makassar. Agrikan 13: 464-469. DOI: 10.29239/j.agrikan.13.2.464-469. [Indonesian]

Hehre EJ, Meeuwig JJ. 2015. Differential response of fish assemblages to coral reef-based seaweed farming. PLos One 10: e0118838. DOI: 10.1371/journal.pone.0118838.

Hehre EJ, Meeuwig JJ. 2016. A global analysis of the relationship between farmed seaweed production and herbivorous fish catch. PLos One 11: e0148250. DOI: 10.1371/journal.pone.0148250.

Hewindati YT, Yuliana E, Winata A, Adimu HE, Djatmiko WA. 2023. Mangrove vegetation and fish diversity in Kaledupa Island, Wakatobi National Park, Southeast Sulawesi, Indonesia. Biodiversitas 24 (3): 1766-1772. DOI: 10.13057/biodiv/d240351.

Horodysky AZ, Cooke SJ, Graves JE, Brill RW. 2016. Fisheries conservation on the high seas: Linking conservation physiology and fisheries ecology for the management of large pelagic fishes. Conserv Physiol 4 (1): 118. DOI: 10.1093/conphys/cov059.

Inyang AI, Wang YS. 2020. Phytoplankton diversity and community responses to physicochemical variables in mangrove zones of Guangzhou Province, China. Ecotoxicology 29: 650-668. DOI: 10.1007/s10646-020-02209-0.

Irawan A, Supriharyono, Hutabarat J, Ambariyanto. 2018. Seagrass beds as the buffer zone for fish biodiversity in coastal water of Bontang city, East Kalimantan, Indonesia. Biodiversitas 19 (3): 1044-1053. DOI: 10.13057/biodiv/d190337.

Isdianto A, Ariefandi MF, Asadi MA, Yamindago A, Setyawan FO, Bintoro G, Setyanto A, Lelono TD, Tumulyadi A, Adhihapsari W, Setyoningrum D, Fathah AL, Putri BM, Supriyadi, Luthfi OM. 2024. Community structure and biomass of reef fish concerning coral cover in Sempu Strait, East Java, Indonesia. Biodiversitas 25 (8): 3376-3385. DOI: 10.13057/biodiv/d250808.

Kaitetu P, Tengah M, Saklíressy A. 2022. Perbedaan ukuran sero tancap terhadap hasil tangkapan di perairan Kaitetu, Maluku Tengah. Jurnal Ilmu Perikanan Kelautan 11: 74-79. [Indonesia]

Krebs CJ. 2014. Ecological Methodology 3rd. Harper Collins Publisher, New York.

Li M, Qu X, Miao H, Wen S, Hua Z, Ma Z, He Z. 2020. Spatial distribution of endemic fluorosis caused by drinking water in a high-fluorine area in Ningxia, China. Environ Sci Pollut Res 27: 20281-20291. DOI: 10.1007/s11356-020-08451-7.

Majhi BM, Dey C, Nath AK. 2024. Fish diversity, assemblage pattern along with the environmental variables in tidal freshwater stretch in the Hooghly estuary of the Gangetic delta, West Bengal, India. Reg Stud Mar Sci 78: 103776. DOI: 10.1016/j.rsma.2024.103776.

Mchich R, Brochier T, Auger P, Brehmer P. 2016. Interactions between the cross-shore structure of small pelagic fish population, offshore industrial fisheries and near shore artisanal fisheries: A mathematical approach. Acta Biotheoretica 64: 479-493. DOI: 10.1007/s10441-016-9299-7.

Musbir, Kurnia M, Sudirman. 2021. Main catch, bycatch, discard catch of set lift net fisheries with light emitting diode (LED) as light attractor in marine coastal waters of Pangkep, Makassar Strait, Indonesia. IOP Conf Ser Earth Environ Sci 763: 012017. DOI: 10.1088/1755-1315/763/1/012017.

Musbir, Bohari R. 2021. Integrate of culture area for seaweed (*Eucheuma cottonii*) and fishing ground for Stripped Mullet (*Mugil cephalus*) in marine coastal waters. IOP Conf Ser Earth Environ Sci 763: 012044. DOI: 10.1088/1755-1315/763/1/012044.

Musbir, Sudirman, Bohari R. 2020. The availability of blue swimming crab (*Portunus pelagicus*, Linnaeus, 1758) in seaweed culture area of marine coastal waters. IOP Conf Ser Earth Environ Sci 564: 012013. DOI: 10.1088/1755-1315/564/1/012013.

Ndobe S, Gani A, Bakri AA, Adriany DT, Wuniarto E, Khartiono LD, Herjayanto M, Hasan V, Moore AM. 2022. First and recurrent records of *Stiphodon surrufus* Watson & Kottelat, 1995 (Gobiiformes, Gobiidae, Sicydiinae), a naturally rare amphidromous goby, in Sulawesi, Indonesia. Check List 18: 253-260. DOI: 10.15560/18.2.253.

Noh JK, Echeverria C, Kleemann J, Koo H, Fürst C, Cuenca P. 2020. Warning about conservation status of forest ecosystems in tropical Andes: National assessment based on IUCN criteria. PLos One 15: e0237877. DOI: 10.1371/journal.pone.0237877.

Nurdin N, Alevizos E, Syamsuddin R, Asis H, Zainuddin EN, Aris A, Oiry S, Brunier G, Komatsu T, Barillé L. 2023. Precision aquaculture drone mapping of the spatial distribution of *Kappaphycus alvarezii* biomass and carrageenan. Remote Sensing 15: 3674. DOI: 10.3390/rs15143674.

Odum EP, Barrett GW. 2005. Fundamental of Ecology, 5th Ed. Cole Publishing Co, Belmont.

Parenden D, Jompa J, Rani C, Renema W, Tuhumena JR. 2023. Biodiversity of hard coral (*Scleractinia*) and relation to environmental factors in turbid waters of Spermonde Islands, South Sulawesi, Indonesia. Biodiversitas 24: 4635-4643. DOI: 10.13057/biodiv/d240903.

Patangngari, Musbir. 2024. Assessing the selectivity level of sero fishing gear using 5 mm and 15 mm mesh sizes installed in the river estuary area. IOP Conf Ser Earth Environ Sci 1410: 012023. DOI: 10.1088/1755-1315/1410/1/012023.

Patangngari F, Amir F, Najamuddin, Jaya I. 2022. Composition of fish catches and environmental friendliness levels based on code of conduct for responsible fisheries (CCRF) using traditional set net fishing gear with different depths in Malela waters, Awangpone district, Bone District. IOP Conf Ser Earth Environ Sci 1119: 012028. DOI: 10.1088/1755-1315/1119/1/012028.

Pessarrodona A, Howard J, Pidgeon E. 2024. Carbon removal and climate change mitigation by seaweed farming: A state of knowledge review. IOP Sci Total Environ 918: 170525. DOI: 10.1016/j.scitotenv.2024.170525.

Ramadhani AA. 2023. Potensi keunggulan kompetitif sumber daya kelautan Indonesia. Jurnal Ekononmi Sakti 12: 291-296. DOI: 10.36272/jes.v12i3.296.

Rasnijal M, Mulyono M, Djunaidah IS. 2021. The performance of *Kappaphycus alvarezii* seaweed cultivation using net bag and non-bag methods in the waters of Bone Gulf, Indonesia. AACL Bioflux 14: 2252-2264.

Rohim N, Sulistiono, Yulianda F, Muhtadi A. 2024. Diversity and ecological drivers of fish in Singkil Swamp Wildlife Reserve, Aceh, Indonesia. Biodiversitas 25: 2849-2856. DOI: 10.13057/biodiv/d250706.

Roy D, Didar NB, Sarker S, Rahman Khan MA, Latifa GA. 2022. Appraisal of different attributes of fish community in Andharmanik River of coastal Bangladesh and socio-economic conditions of fishermen. Heliyon 8: e09825. DOI: 10.1016/j.heliyon.2022.e09825.

Saanin H. 1995. Taxonomy and Key to Fish Identification I and II. Bina Cipta, Bogor. [Indonesian]

Siriwattanarat R, Wongroj W, Ngamniyom A, Vilasri V, Chungthanawong S, Punnarak P. 2024. Fish diversity and environmental factors at the Don Hoi Lot Ramsar Site, Thailand. Biodiversitas 25 (4): 1394-1403. DOI: 10.13057/biodiv/d250407.

Sudirman. 2018. Metode Penangkapan Ikan. Universitas Terbuka, Tangerang Selatan. [Indonesian]

Sukimin R, Danial D, Rauf A 2021. Study of several aspects of fishery for guiding barrier fishing gear in the coastal town Palopo. J Biol Trop 21: 564-575. DOI: 10.29303/jbt.v21i2.2743.

Tuncharoen S, Manetam K, Pornpuang S, Chaisan W, Panprommin D, Soonthornprasit K, Pitakpol S. 2024. Fish diversity in the Nong Leng Sai Wetland, Phayao Province, Northern Thailand, after deep-water dredging. Biodiversitas 25: 2738-2746. DOI: 10.13057/biodiv/d250644.

Vega-Cendejas ME, de SMH, Chi-Espínola A, Aguilar-Medrano R. 2023. Fish community structure along a depth gradient at the Western Gulf of Mexico. Reg Stud Mar Sci 68: 103237. DOI: 10.1016/j.rsma.2023.103237.

Yonvitner, Boer M, Kurnia R. 2020. Kajian tingkat efektivitas perikanan untuk pengembangan secara berkelanjutan di Provinsi Banten. Jurnal Kebijakan Perikanan Indonesia 12: 35-46. DOI: 10.15578/jkpi.12.1.2020.35-46. [Indonesia]
Zhang K, Sun C, Shi W, Lin J, Li B, Liu W, Chen D, Zhang A. 2024. Turbidity-tolerant underwater wireless optical communications using dense blue-green wavelength division multiplexing. Optics Express 32: 20762-20775. DOI: 10.1364/oe.521575.
Zhao J, Li C, Wang T, Li C, Shen J, Liu Y, Wu P. 2022. Distribution pattern of mangrove fish communities in China. Biology 11: 1696. DOI: 10.3390/biology11121696.
Zhou W, Li X. 2024. Fish diversity and selection of taxa for conservation in the Salween and Irrawaddy Rivers, Southeast Asia. Sci Rep 14: 2393. DOI: 10.1038/s41598-024-51205-5.