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Modeling the tropical fish community related to land uses and environmental determinants

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ABSTRACT

BACKGROUND AND OBJECTIVES: Coastal ecosystems worldwide have been threatened by changing land use and environmental determinants. These conditions have impacted important marine resources, including fish diversity. Southeast Asia, one region experiencing massive land use change, still has limited information on how land use and disturbed coastal ecosystems impact fish diversity. This information is urgently needed as fish is one of the most important food resources here. This study aims to assess and compare the environment and tropical fish community between disturbed and intact sites, represented by coasts dominated by settlements and coasts dominated by mangrove forests in West Java, Indonesia.
METHODS: Fish sampling was carried out at two sites: Jakarta as the disturbed site and Subang as the intact site; water quality was also measured at these sites. Land uses at the sites were interpreted using satellite imagery. Fish diversity was determined using the Shannon–Wiener index, rarefaction curve, and Lorenz graph. Principal component analysis, analysis of variance, and the x2-test were used to determine environmental factors that affected the fish community at both sites. Akaike's information criterion was assigned to model the relationship between environmental factors and the fish community.
FINDINGS: Coasts characterized by anthropogenic disturbances and the absence of mangrove cover have a lower potential of hydrogen (pH) and reduced fish diversity by up to 53.91%. The intact site had higher fish diversity and made a greater contribution to conservation by providing habitats for fish species with the least concern and vulnerability statuses, according to the International Union for Conservation of Nature Red List. From the AIC model, the decreasing water pH (AICc = 27.28) was the main determinant that reduces fish diversity at disturbed sites compared to dissolved oxygen (Akaike's information criterion = 28.13) and salinity (Akaike's information criterion = 29.95).
CONCLUSION: The coastal fish community was affected by differences in environmental factors, land uses, and mangrove cover driven by anthropogenic influences. The AIC model proved capable of assessing the effects of environmental factors on coastal fish communities. This study modeled environmental factors that should be managed and prioritized to restore and conserve the fish community along tropical coasts.

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INTRODUCTION

Marine ecosystems, including coastal ecosystems, are subjected to several anthropogenic activities. The loss of coastal biodiversity has become a well-recognized feature of the Anthropocene. Anthropogenic disturbances caused by activities such as agriculture, massive urbanization, deforestation, and introduction of non-native species may contribute to the diversity of fish species within a community, for example, the reduction in fish diversity and the increased similarity in composition of fish species (Dornelas *et al*., 2014; Socolar *et al*., 2016). The disturbance induced by human activities in an intact ecosystem can promote the replacement of many endemic species with cosmopolitan fish (Li *et al*., 2018). Environmental disturbances related to anthropogenic activities include small farms, tourism, and fishing fleets (Méndez, 2021). Anthropogenic activities have been widely reported to have negative impacts on coastal ecosystems from the tropics to Antarctica. Even in remote places like Antarctica, the disturbed area along the coast showed lower values of biodiversity and taxonomic distinctness (Stark *et al.*, 2014), because of anthropogenic activities and disturbances in the form of old waste disposal sites, environmental pollution, and organic enrichment. Palacios-Sánchez *et al*. (2019) confirmed that the presence of anthropogenic impacts reduced salinity, fish abundance, and biodiversity values, as observed in the disturbed coasts receiving medium to high impacts. Nevertheless, the category of coasts without impacts has high values of fish diversity and abundance, and salinity, but low concentrations of nitrites, nitrates, and ammonia. In seagrass ecosystems (Iacarella *et al.*, 2018) near the coast, associated with high anthropogenic disturbance, the fish composition exhibits biotic homogenization. A site with this high disturbance was reported to have lower biodiversity than an area with low disturbance (Fakhry *et al.*, 2020). The Southeast Asian region is known for its vast and lucrative tropical coasts that have high fish diversity. In this region, coastal ecosystems located on the West Java coast are known to have high fish species biodiversity, which include families of Leiognathidae (*Leiognathus* spp.), Sciaenidae, Synodontidae (*Saurida tumbil*), Bothidae, Ariidae (*Netuma thalassina*), Plotosidae, Nemipteridae (*Nemipterus hexodon*), Clupeidae, and Haemulidae (Partasasmita *et al*., 2015). However, this coast has been recently threatened (Nuryanto *et al.*, 2021) and disturbed by the presence of anthropogenic influences and land-use conversion from intact mangrove forests to human settlements (Fabinyi *et al*., 2022). In Indonesia, comparative studies on the fish community in both protected and disturbed environments are still lacking; however, this information is urgently needed as fish communities are threatened by the magnitude of anthropogenic activities on coasts. Currently, the West Java coast is threatened by population density and anthropogenic activities that have led to land-use change, reduced carrying capacity, and increased impacts on environmental quality (Handayani *et al*., 2017). The West Java coast has a population of 35 million, and this keeps increasing. This makes it the second largest urban population in the world (Octifanny and Hudalah, 2017) and can pose a significant threat to coastal fish resources. Considering this situation, this study attempts to address the following questions: are there any differences in the fish community between coasts disturbed by anthropogenic activity and intact coasts? If there is a difference, what are the primary environmental determinants affecting the fish community? The assessment was based on Akaike's information criterion (AIC) modeling as this method can select environmental factors that should be managed and prioritized to restore and conserve the fish community along disturbance gradients. Assessment and modeling results can then be applied to strategize the management and conservation of coastal fish, especially in controlling anthropogenic activities and regulating environmental factors related to those activities. The objectives of this study are to assess and compare the environment and tropical fish community between disturbed and intact sites, represented by disturbed coasts dominated by settlements (Jakarta coast) and intact coasts dominated by mangrove forests (Subang coast), on the West Java coast, Indonesia, in 2022.

MATERIALS AND METHODS

Study area

The northern West Java coastal areas, Indonesia, consisting of Jakarta and Subang (western part/ West Java coast), were selected as the study areas representing disturbed and intact sites, respectively (Fig. 1). The determinations of disturbed and intact sites were based on literature reviews, field

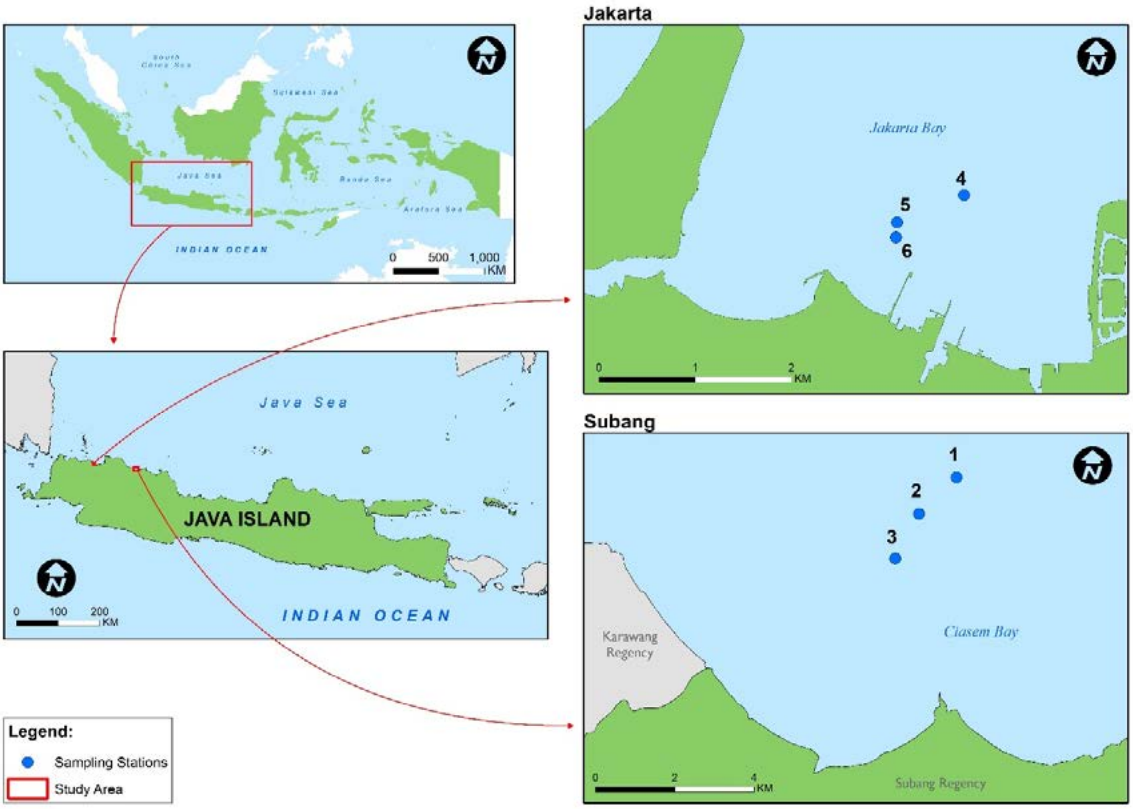

Fig. 1: Geographic location of the study area at disturbed and intact sites on West Java coast, Indonesia

observations, and satellite image classification using geographical information system (GIS) analyses. The disturbed site was part of Jakarta city, with the geographical location of between 6.103º and 6.108º south latitude (SL) and 106.773º and 106.779º east longitude (EL). These sites are characterized by the absence of natural cover, including mangrove forests, as the natural vegetation has been converted into settlements. Driven by economic growth and high population growth in Jakarta, there have been massive developments of residential and infrastructure areas in Jakarta. Besides the settlements, there are seaports and industrial areas. As a result, residential and infrastructure area expansion has disturbed the mangrove forest cover in Jakarta, reducing mangrove areas by up to 393 hectares from 1998 to 2018 (Rizal and Haykal, 2021). Despite these massive anthropogenic disturbances, the body of water off the coast is still utilized by traditional fishermen to catch some fish species. The population of the disturbed site was 1.8 million. The intact site was part of the Subang district, with coordinates of 6°12’50.4”SL, 107°38’38.4”EL - 6°13’19.2” SL, 107°41’38.4”EL. This sites is characterized by a combination of fishponds with reforested mangroves and the presence of intact mangrove forests. This site was previously covered by vast mangroves. However, those intact mangroves were deforested and converted into fishponds. As a result of awareness of the community and fishermen, the logged mangrove forest has been restored through reforestation. The results were mangroves covered with fishponds. The water near the coast is known to have numerous fish species of commercial value, which can be either consumed or sold in the market. The population of the disturbed site was only 64,235 people.

Fish survey

The procedure for the fish survey was modified from previous studies (Agustriani *et al*., 2020; Araújo *et al*., 2006). The survey was conducted in the daytime, from 8.00 am to 14.00 pm. Gillnets with a mesh size of 2 inches were used to capture fish. The fish collected were preserved using 10% formaldehyde. Fish identification was conducted based on their morphological characteristics, using the identification key provided in the guidebook by Kottelat *et al.* (1993).

Environmental variable measurements

Environmental variables, such potential of hydrogen (pH), salinity, and dissolved oxygen (DO), were recorded in situ. Each variable was noted with three replications for each sampling location. The equipment used to measure the variables were the Lutron DO meter 5510 for DO values, Lutron pH meter 5510 for pH, and Atago refractometer for salinity. The site coordinates were plotted using the Garmin eTrex global positioning system (GPS).

Data analyses

Coastal land uses

A GIS was used to classify land use in the coastal area. Images captured using Landsat 8 were reacquired and supervised to obtain the type of land use. The categories for coastal land-use classifications were water and sea, mangrove, mangrove and fishpond, and settlement. Then, the compositions of each land-use type were denoted as percentages.

Fish species diversity

The diversity of fish species was determined using the Shannon–Wiener diversity index. This index was applied to measure the diversity of fish species in both disturbed and intact sites using Eq. 1 (Roy *et al*., 2022).

$$H' = -\sum_{i=1}^{S} p_i \ln p_i$$

Where, H' is the Shannon–Wiener index, pi is the proportion of the total abundance of the community represented by the i-th species, ln (pi) is the natural log of pi, S is the number of fish species encountered, and Σ is the sum of species 1 to species S.

Rarefaction curves and Lorenz graphs

Fish diversity was modeled using the rarefaction curve (Nuon *et al*., 2020) and Lorenz graph. The Lorenz graph indicates diversity based on the evenness. Within the Lorenz graph, the diversity was measured based on the curve shapes under the diagonal line representing the evenness. The greater the curve of the evenness line, the more diverse the particular species becomes and the more uneven the abundance of each fish species becomes (Nijssen *et al*., 1998; Rousseau *et al*., 1999; Tallei *et al*., 2018).

Principal component analysis (PCA), analysis of variance (ANOVA), and x^2-test

PCA, an ordination method, was used to visualize the patterns of diversity values (H') and environmental variable data between the disturbed and intact sites (Chen *et al*., 2022). The significance of the effects of disturbances on the H', DO, salinity, and pH was tested using ANOVA (Caliman *et al*., 2013). The x^2-test was used to test the differences of land-use compositions.

Akaike information criterion (AIC) model

Fish community correlations with environmental variables in both disturbed and intact sites were modeled using AIC, following Cavada *et al*. (2016). The AIC model was developed using linear regression (Smoliński and Radtke, 2017; Wedding *et al*., 2019). The parameters measured included in AIC were AIC_c, ΔAIC_c, AIC_c weight, cumulative weight, and log likelihood. To develop the model, environmental variables correlated with the fish biodiversity index (H'), including pH, DO, and salinity, were analyzed. To investigate which is the best model, the following seven linear mixed-effect models were applied and compared as follows:

Model 1: Salinity effect
Model 2: DO effect
Model 3: pH effect
Model 4: Salinity + DO effect
Model 5: Salinity + pH effect
Model 6: DO + pH effect
Model 7: Salinity + DO + pH effect

The best model was selected based on the lowest AIC_c and cumulative weight values.

RESULTS AND DISCUSSION

Coastal land uses

Land-use characteristics are one of the important pieces of information recorded in this study as they play a significant role in influencing the environmental determinants and fish species diversity. Based on the statistical results, a significant difference in land-use compositions was found (x^2 = 23.532, $P < 0.05$)

(Fig. 2). The coastal disturbed site was dominated by settlements. In comparison, settlements were absent at the intact site. At the intact site, intact mangroves and reforested mangroves were more common and dominant (Fig. 3).

The significant differences in land-use types between both sites affected fish species diversity and environmental determinants. The average fish species diversity, denoted as H', reduced by 53.91% from 2.17 (95% confidence interval [CI]: 1.15–3.19) to as low as 1 (95% CI: 0.018–1.98) (Table 1). Some environmental determinants were also affected (Fig. 4). The water at the disturbed site was becoming more acidic than that at the intact site ($F = 220.516$, $P < 0.05$). The disturbed site had lower salinity because of the presence of 13 rivers at this site that discharge freshwater.

These findings on how coastal land uses influence the ecosystem along with fish species diversity agree with those of previous studies (Qiao *et al*., 2022). In the Southeast Asian region, as observed in Sabah (Tóth *et al*., 2019), land-use changes in protected intact areas reduced the species and functional richness of native fish. Any form of logging or land-use change has had a clear and negative impact on fish communities. As a consequence of anthropogenic disturbances, low H' values can also be caused by the presence of invasive fish species that replace native species. Conversions of intact vegetated areas into agricultural areas have caused non-native fish to modify the structure of native fish communities (Wilkinson *et al*., 2018).

Fish community assemblage

In total, 11 species from 11 families were found in the disturbed site (Table 2). Species belonging to Leiognathidae, Haemulidae, and Sciaenidae were

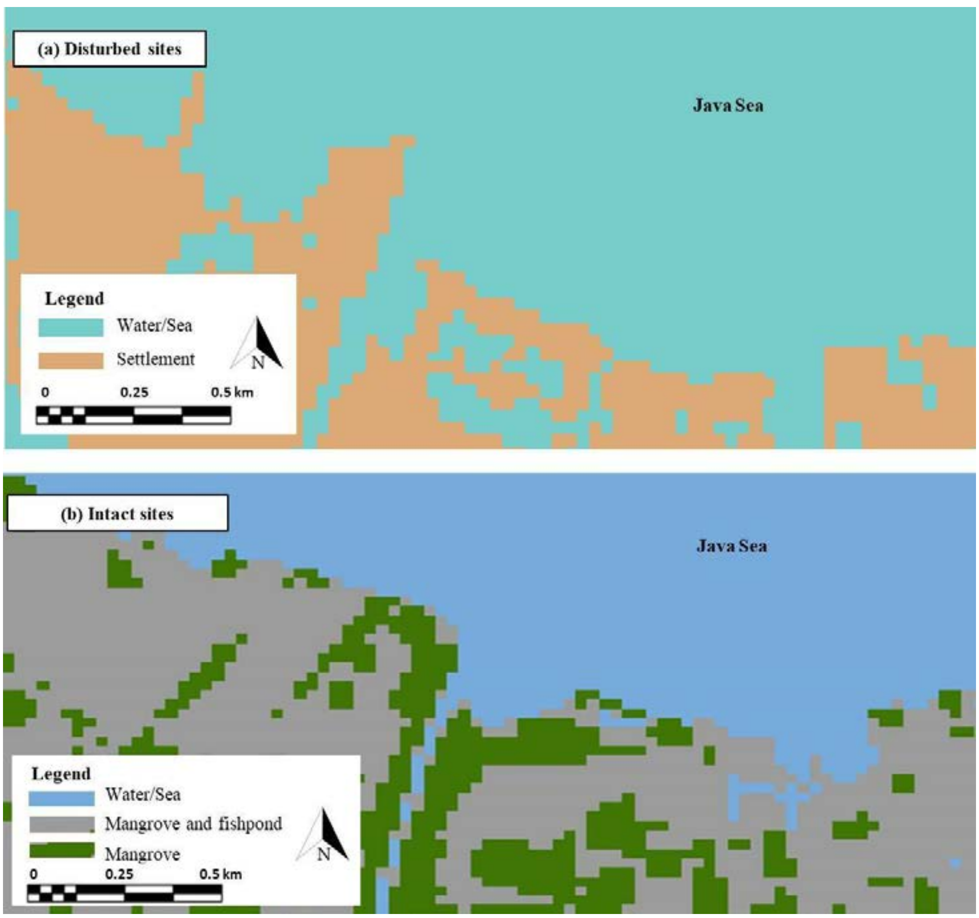

Fig. 2: Land-use classifications at disturbed and intact sites on West Java coast

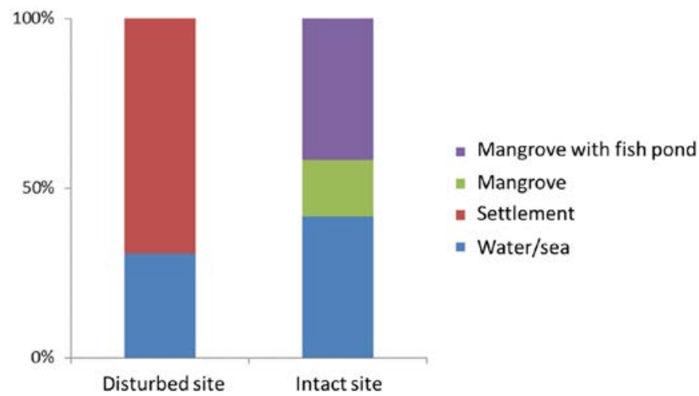

Fig. 3: Land-use compositions at disturbed and intact sites on West Java coast

Table 1: Summary of the mean and 95% CI and ANOVA for effects of disturbances on H’, DO, salinity, and pH at disturbed and intact sites

Source of variations	Mean and 95% CI		F	P
	Disturbed	Intact		
H’	1 (0.018–1.98)	2.17 (1.15–3.19)	2.606	0.181
DO	19 (17.3–20.7)	6.33 (6.19–6.47)	220.516	0.000
pH	6.99 (6.76–7.22)	7.7 (7.59–7.81)	29.337	0.005
Salinity	24 (12.6–35.4)	35.5 (34.4–36.6)	3.851	0.121

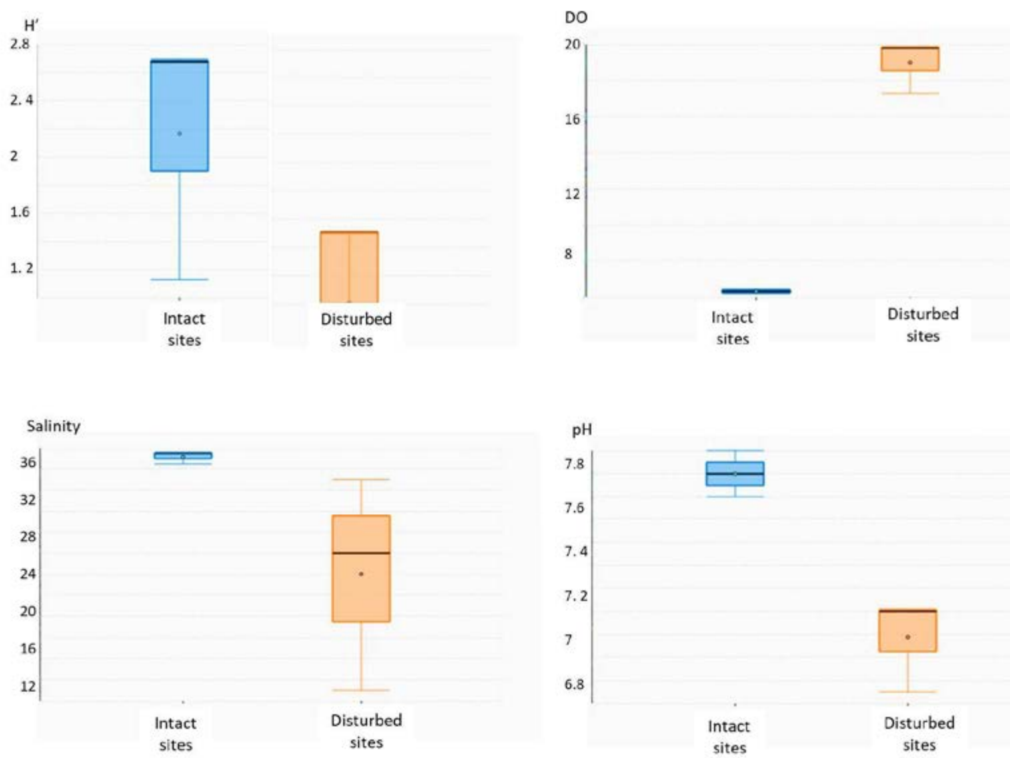

Fig. 4: Comparisons of H’, DO, salinity, and pH between disturbed (a) and intact (b) sites on West Java coast

Table 2: Fish species list recorded with family, common name, and individual abundance at disturbed (A) and intact (B) sites on West Java coast

Scientific name	Common name	Family	IUCN	A	B
Leiognathus equulus (Forsskål, 1775)	Common ponyfish	Leiognathidae	LC	6	-
Leiognathus brevirostris (Cuvier and Valenciennes, 1835)	Shortnose ponyfish	Leiognathidae	NE	-	1
Deveximentum insidiator (Bloch, 1787)	Pugnose ponyfish	Leiognathidae	NE	-	3
Photopectoralis bindus (Cuvier and Valenciennes, 1835)	Orangefin ponyfish	Leiognathidae	NE	-	1
Nuchequula nuchalis (Temminck and Schlegel, 1845)	Spotnape ponyfish	Leiognathidae	NE	-	4
Sphoeroides pachygaster (Müller and Troschel, 1845)	Blunthead puffer	Tetraodontidae	V	1	-
Lagocephalus spadiceus (Richardson, 1845)	Half-smooth golden pufferfish	Tetraodontidae	LC	-	3
Sardinella brachysoma (Bleeker, 1852)	Deepbody sardinella	Clupeidae	NE	1	-
Tenualosa toli (Cuvier and Valenciennes, 1847)	Toli shad	Clupeidae	V	-	1
Plotosus lineatus (Thunberg, 1787)	Striped eel catfish	Plotosidae	NE	1	-
Hexanematichthys sagor (Hamilton, 1822)	Sagor catfish	Ariidae	NE	1	12
Scatophagus argus (Linnaeus, 1766)	Spotted scat	Scatophagidae	LC	2	-
Sphyraena obtusata (Cuvier, 1829)	Obtuse barracuda	Sphyraenidae	NE	1	-
Platycephalus indicus (Linnaeus, 1758)	Bartail flathead	Platycephalidae	DD	1	1
Abalistes stellaris (Anonymous, 1798)	Starry triggerfish	Balistidae	NE	1	-
Pomadasys argenteus (Forsskål, 1775)	Silver grunt	Haemulidae	LC	23	-
Larimichthys pamoides (Munro, 1964)	Southern yellow croaker	Sciaenidae	LC	11	-
Pennahia argentata (Houttuyn, 1782)	Silver croaker	Sciaenidae	LC	-	26
Gerres oyena (Forsskål, 1775)	Common silver-biddy	Gerreidae	LC	-	1
Lutjanus russellii (Bleeker, 1849)	Russell's snapper	Lutjanidae	LC	-	2
Lutjanus stellatus (Akazaki, 1983)	Star snapper	Lutjanidae	NE	-	1
Thryssa mystax (Bloch and Schneider, 1801)	Moustached thryssa	Engraulidae	LC	-	9
Upeneus sulphureus (Cuvier, 1829)	Sulfur goatfish	Mullidae	LC	-	2
Epinephelus polyphekadion (Bleeker, 1849)	Camouflage grouper	Serranidae	V	-	1
Scomberomorus commerson (Lacepède, 1800)	Narrow-barred Spanish mackerel	Scombridae	NT	-	1
Lepturacanthus savala (Cuvier, 1829)	Savalai hairtail	Trichiuridae	NE	-	3
Nemipterus virgatus (Houttuyn, 1782)	Golden threadfin bream	Nemipteridae	V	-	1
Pampus argenteus (Euphrasen, 1788)	Silver pomfret	Stromateidae	NE	-	1
Calloplesiops altivelis (Steindachner, 1903)	Comet	Plesiopidae	LC	-	5
Pomadasys kaakan (Cuvier, 1830)	Javelin grunter	Haemulidae	NE	-	6
Cynoglossus lingua (Hamilton, 1822)	Long tongue sole	Cynoglossidae	LC	-	3
Spratelloides gracilis (Temminck and Schlegel, 1846)	Silver-stripe round herring	Spratelloididae	LC	-	2
Sillago sihama (Forsskål, 1775)	Silver sillago	Sillaginidae	LC	-	1
Glossogobius giuris (Hamilton, 1822)	Tank goby	Gobiidae	LC	-	1
Crenimugil seheli (Forsskål, 1775)	Bluespot mullet	Mugilidae	LC	-	23
Eleutheronema tetradactylum (Shaw, 1804)	Fourfinger threadfin	Polynemidae	NE	-	2
Chanos (Forsskål, 1775)	Milkfish	Chanidae	LC	-	1
Terapon jarbua (Forsskål, 1775)	Jarbua terapon	Terapontidae	LC	-	3

DD: data deficient; NE: not evaluated; LC: least concern, V: vulnerable

more abundant than other species and families. At the intact site, there were 29 species belonging to 25 families. Species belonging to Mugilidae, Sciaenidae, and Ariidae were more abundant than other species and families. The presence of high numbers of individuals and families in the intact site confirms that fish species at this site are more diverse and abundant. According to the rarefaction curve and Lorenz graph (Figs. 5 and 6), a small sample taken from the intact site yielded more fish species than a sample taken from the disturbed site. Some fish species were restricted to either the intact or disturbed sites, whereas other fish species were more general. At the disturbed site, 36% of recorded species were found only at this site, and these species include Plotosidae, Scatophagidae, and Sphyraenidae. At the intact site, up to 65% of fish species were found to be limited to this site. About 63% of fish species at the disturbed site were also found at the intact site, and as low as 27% of fish species at the intact site were also found at the disturbed site. As the disturbed site have more common fish species, this indicates that disturbance

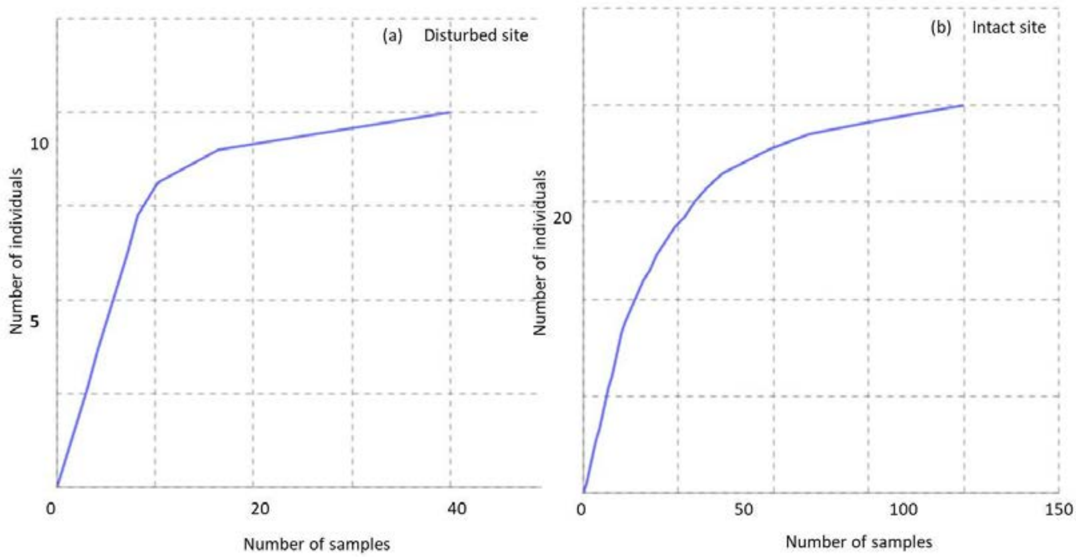

Fig. 5: Rarefaction curves of fish species at disturbed (a) and intact (b) sites on West Java coast

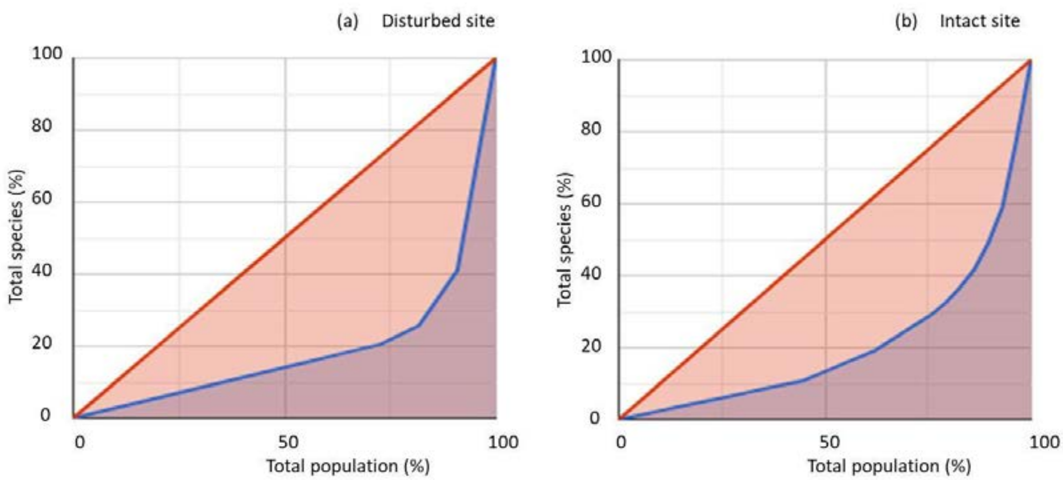

Fig. 6: Lorenz graphs of fish species at disturbed (a) and intact (b) sites on West Java coast

can cause a homogenization of fish species (Fig. 7). Regarding the International Union for Conservation of Nature (IUCN) Red List, more vulnerable and least concern fish species were recorded at the intact site. This indicates that the intact sites make greater contributions to conservation as they provide protection to and habitats for threatened fish species (Fig. 8).

The changing fish assemblages between disturbed and intact sites are related to land use that influences nutrient discharge into the waters. Urban areas with higher human populations are subjected to inputs of anthropogenic waste and characterized by alterations of intact ecosystems to settlements and agriculture, which discharge large quantities of nutrients and waste nitrogen. The accumulation of nitrogen

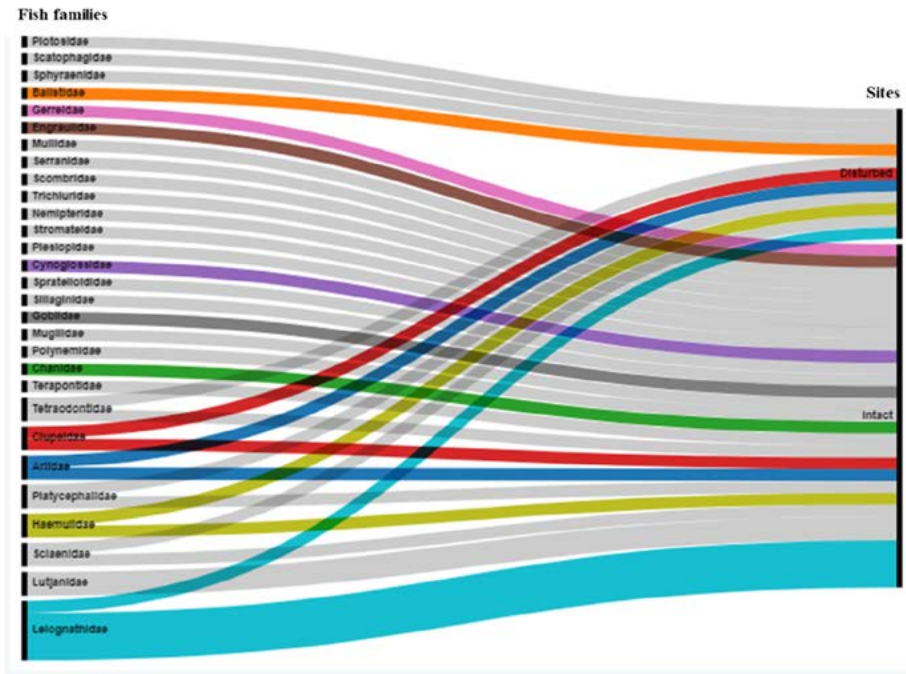

Fig. 7: Fish family compositions at disturbed (a) and intact (b) sites on West Java coast

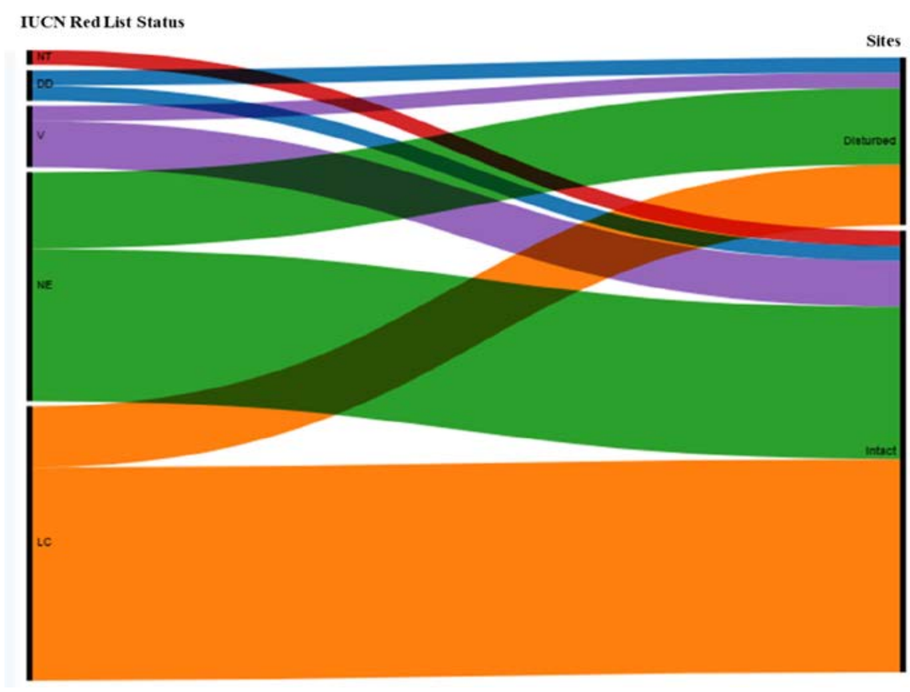

Fig. 8: Fish IUCN Red List Status compositions at disturbed (a) and intact (b) sites on West Java coast (DD: data deficient; NE: not evaluated; LC: least concern, V: vulnerable)

increases the abundant plankton and aquatic plants, followed by increases in planktivore and herbivore species only, which replaces other guilds (Britton *et al*., 2019). Coastal land use for human activities is intrinsically linked to ecological conditions in coastal environments. Nearby mangrove cover removal either at a catchment scale or at a local scale increases the input of sediments and nutrients into coastal ecosystems near terrestrial ecosystems and mangrove cover (Tibúrcio *et al*., 2016). On the contrary, intact vegetation cover is known to improve water quality, availability and stability of physical complex structures, and availability and diversity of food items for fish (Lo *et al*., 2020). As a result, as observed in this study, forested sites host higher fish abundance because fish often actively select mangrove forests in searching for suitable habitat conditions (Castello *et al*., 2022). The presence of mangrove cover benefits the fish community (Hutchison *et al*., 2014) by providing nursery grounds, food resources, and protection from predators. Rogers and Mumby (2019) reported that the presence of mangroves can increase fish productivity.

Fish community and environmental models

The ordination of disturbed and intact sites by PCA of environmental variables (Fig. 9) demonstrated some probable relationships among them. For instance, the intact site was characterized by high diversity, alkaline water with high pH values, saline water, and low DO values. At the intact site, fish diversity tended to be positively correlated with increases in pH, salinity, and DO. Conspicuously, the DO was negatively correlated with fish diversity, pH values, and salinity. In contrast, the disturbed site was characterized by low diversity, acidic water with low pH values, less saline water, and high DO values.

Table 3 shows the model for the fish community and environmental determinants represented by AIC_c and cumulative weight. Two models had the lowest AIC_c and cumulative weight, indicating that they were the best models. These models include the effects of DO and pH determinants. The summed AIC_c and cumulative weight for these determinants were 27.28

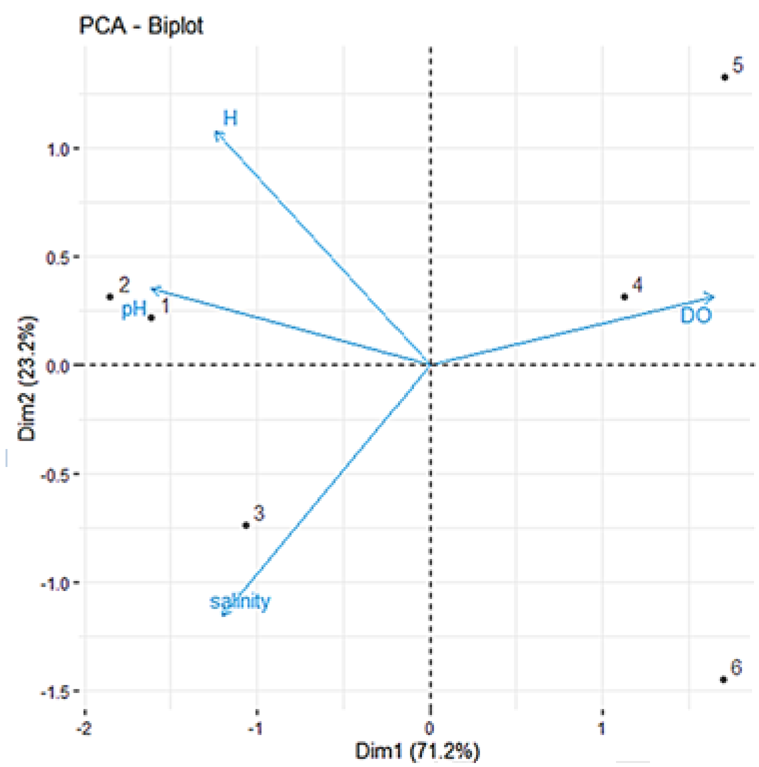

Fig. 9: PCA plot showing intact (1, 2, 3) and disturbed (4, 5, 6) sites related to H', DO, salinity, and pH

Table 3: AIC models of fish diversity (H’) with H’, DO, salinity, and pH variables at intact and disturbed sites on West Java coast

Fish diversity models	AIC_c	ΔAIC_c	AIC_c weight	Cum. weight	Log likelihood
Model 1: H’~salinity	29.95	2.67	0.14	1.00	-5.97
Model 2*: H’~DO	28.13	0.85	0.34	0.86	-5.07
Model 3*: H’~pH	27.28	0.00	0.5234	0.52	-4.64
Model 4: H’~salinity+DO	57.66	30.38	0.00	1.00	-4.83
Model 5: H’~salinity+pH	57.28	29.99	0.00	0.00	-4.64
Model 6: H’~DO+pH	57.28	30.00	0.00	1.00	-4.64
Model 7: H’~salinity+DO+ pH	na	na	0.00	1.00	-4.63

Table 4: Comparisons with current studies on fish community

Region	Location	Species	Data analysis	Source
Indonesia	Lake Siawan, West Kalimantan province	57	Shannon–Wiener H’	Haryono (2020)
Indonesia	Banten Bay, Banten province	52	Shannon–Wiener H’	Sugiarti *et al*. (2021)
Indonesia	Paraja Bay, Banten province	106	Shannon–Wiener H’	Mujiyanto *et al.* (2021)
Malaysia	Bidong island, South China Sea	89	Shannon–Wiener H’	Rumeaida *et al.* (2014)
Thailand	Ban Pak Klong, Trang province	62	Shannon–Wiener H’	Phinrub *et al*. (2014)
India	Western coast	212	Fish community index	Bella *et al.* (2021)
Indonesia	Jakarta, Jakarta province	29	Shannon–Wiener H’, AIC model	This study
Indonesia	Subang, West Java province	11	Shannon–Wiener H’, AIC model	This study

and 0.52 for pH determinants and 28.13 and 0.86 for DO determinants, respectively. The summed AIC_c and cumulative weight for Akaike weight as low as 27.28 and 0.52 indicate significant effects of pH variations on fish species diversity. The second important effect was DO, followed by salinity. Then, the suggested model equations are H’~DO and H’~pH. The other five models of fish communities that incorporate salinity and the combined effects of salinity and pH, salinity and DO, salinity and DO and pH, and DO and pH were not suggested because those models have higher AIC_c and cumulative weight values than the suggested best models.

Cum., cumulative; na, not available

AIC was chosen and used as one of the methods for determining which environmental determinant has the greatest impact on specific fish diversity. This method has been used to model the effects of various environmental determinants, including the year, lunar cycle, and tide, on several fish families (Powell *et al*., 2016). This study is comparable with current research on fish communities at the national, Southeast Asian, and Asian levels (Table 4). Studies in numerous Indonesian provinces represent the current work on the fish community at the national level. Meanwhile, studies in Malaysia and Thailand represent the current Southeast Asian work. A study from India represents the current work on the fish community at the Asian level. However, the current studies have a limitation in their methods. The data analysis method in most current studies is limited to the Shannon–Wiener H’. To fill this gap and provide a better understanding of the fish community along with its determinant factors, this study implemented the AIC model as the sole data analysis method. This is clearly progress compared to current similar studies in that there is a paucity of fish community modeling. In this study, AIC was used to determine that pH is the environmental determinant that most affects fish species diversity. At the intact site, the environmental condition is indicated by the alkaline water with a higher pH that has converse effects on fish species diversity. In comparison, water at the disturbed site is more acidic and it reduces fish species diversity. These findings are in agreement with those of previous studies. In acidic aquatic environments, the aquatic organism diversity was lower than that in acidic aquatic environments with higher pH, and these results were statistically significant. It is clear that acidification (Spyra, 2017) negatively affects ecosystem function (Alam *et al*., 2021) and diversity because of the elimination of fish species that are most sensitive to the low pH of water (Hall-Spencer and Harvey, 2019).

CONCLUSION

The coast is an important area because it is basically composed of various ecosystems, including mangroves, coral reefs, sea grasses, and sandy beaches, which are interrelated with each other. Coastal areas are also influenced by various kinds of anthropogenic activities, either directly or indirectly, as well as natural processes that are found on land and at sea. Here, this study succeeded in modeling coastal fish communities on the northern West Java coast, covering both disturbed and intact sites. This study has added value to current research on the fish community by using an AIC model. The AIC model of the fish community resulting from this study can be applied to other coastal areas affected by anthropogenic activities. The model can be used to determine which environmental factors should be regulated to restore and conserve the fish community. This study confirms that the numbers of fish species found at the disturbed site were lower than those at the intact site. More fish species are found at the intact site with H' values of 2.17, and vulnerable species are found at the intact site compared to the disturbed site. The fish community showed lower homogeneity at the intact site, which indicated that more species could thrive at the intact site and more niches were available within the ecosystem. In this AIC model, three main environmental determinants of DO, pH, and salinity were tested for their relative impacts on fish biodiversity. The model discovered that the most important factor in determining fish biodiversity was pH. Based on the model, the summed AIC_c and cumulative weight for Akaike weight were as low as 27.28 and 0.52, indicating significant effects of pH variations on fish species diversity. Thus, coastal conservation management should make the maintenance of more natural coastal systems at intact sites their main priority, as well as restore and improve environmental quality at disturbed sites. Both these objectives could be achieved through a moratorium on development and simultaneous mangrove planting.

AUTHOR CONTRIBUTIONS

N.D. Takarina as corresponding author contributed to the funding, proposal, and drafting of the manuscript. O.M. Chuan prepared the manuscript, reviewed the proposals, and verified the data. M.I. Afifudin conducted fish sampling in Jakarta and tabulated the data. L. Tristan conducted fish sampling in Subang and counted and identified the samples. I. Arif prepared the samples and tabulated the data. A. Adiwibowo drafted the manuscript and analyzed and interpreted the data.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancy have been completely observed by the authors.

ABBREVIATIONS

o	Degree
%	Percentage
Σ	Sum of species 1 to species S
am	Ante meridiem
ANOVA	Analysis of variance
AIC	Akaike information criterion
AIC_c	Akaike information criterion factor i
ΔAIC_c	Akaike information criterion delta/sum
CI	Confidence interval
DD	Data deficient
DO	Dissolved oxygen
EL	East longitude
F	Means between population/ distribution
GIS	Geographical Information System
GPS	Global Positioning System
H'	Shannon–Wiener index
in	Inch
IUCN	International Union for Conservation of Nature
LC	Least concern
ln	Natural log
N	North
na	Not available
NE	Not evaluated
P	Probability / significant value
PCA	Principal component analysis
pH	Potential of hydrogen
p_i	Proportion of the entire community made up of species i
pm	Post meridiem
S	Number of fish species encountered
SL	South latidude
V	Vulnerable
x^2	Chi square

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