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The association of economically important fish with mangroves in Maumere Bay, Indonesia

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Abstract. Mangroves are known to play a role in fisheries production, but specifically, however the associations between economically important fish species and mangroves with varied characteristics are not yet widely known. The aim of this study was to analyse the relationship (association) between economically important fish species and mangroves with varied characteristics in Maumere Bay, Indonesia. The research used spatial and non-spatial methods; the research on economically important fish species used an experimental fishing sampling method. Correspondence analysis was applied to answer the question why certain economically important fish species were associated with certain mangrove characteristics. The mangroves at the study locations with characteristically dominant species *Bruguiera parviflora, Avicennia alba, Bruguiera gymnorrhiza, Ceriops tagal*, with a moderate value of the Shannon diversity index ($1 < H' \leq 3$), and moderate value of the Simpson dominance index ($0.5 < C \leq 0.75$), associated with the economically important fish species *Psammoperca waigiensis, Synanceia verrucosa* and *Pomadasys maculatus*. The locations of mangrove with high mangrove cover (≥ 80%), *Avicennia marina* as dominant species, large area (100 ha) and high density (≥ 3000 trees / ha), *Rhizophora mucronata* as dominant species, and high value of Pielou's evenness index ($0.6 < e \leq 1.0$) were associated with the economically important fish species *Upeneus mollucensis, Lethrinus lentjan,* and *Lutjanus bitaeniatus*. The mangrove locations with medium cover (50% - 75%), moderate values of Simpson dominance index ($0.5 < C \leq 0.75$) but high mangrove belt width (≥ 400 m) were associated with the economically important fish species *Siganus javus, Stegostoma fasciatum, Mugil cephalus, Carangoides malabaricus* and *Chanos chanos*.

1. Introduction

Mangrove forests are widely recognized as having a role in improving small and medium scale fisheries [1], and mangroves are closely related to fisheries production [2]. Mangroves have a function as spawning grounds, feeding grounds and nursery grounds for many species. They are important for both commercial and subsistence fisheries, including finfish, shellfish and crustacean [1]. Although the benefits to fisheries from mangroves are widely known [3,4], research that measures the actual contribution of mangroves to fisheries is still limited [5]. This deficiency is particularly striking in Indonesia, at the heart of the Indo-Pacific Coral Triangle Biodiversity Hotspot, which is also a centre of mangrove and fish biodiversity [6–8]. The next question is: what is the association between mangroves and certain economically important types of fish? The information that can answer these questions was not available.

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Meanwhile, the characteristics of mangrove forests can be described by a number of variables, including mangrove belt width and area, mangrove percentage cover, mangrove density and dominance, and several ecological indices. The questions arise, mangrove forests with various characteristics are associated with what types of economically important fish, and why do these associations occur.

The aims of this study were to analyse the relationship (or association) between economically important fish species and mangroves with varied characteristics, specifically in Maumere Bay, Indonesia. This research is important, considering that Indonesia is the centre of world mangrove diversity [7].

2. Methods

Mangrove data collected for this study consisted of spatial data (mangrove belt width and area, mangrove cover) and non spatial data (mangrove density and dominance). Mangrove belt width and area were analysed using satellite images Landsat ETM 7 and Landsat OLI/TIRS from 2017. For mangrove cover band composite RGB 4–5–3 from Landsat ETM 7 was used, as well as RGB 5–6–4 Landsat 8 false colour composite. Transect line plots (quadrats) were used to collect in situ non spatial mangrove data.

The study was conducted from September 2017 – October 2018. Sampling was conducted at 7 stations, with three substations as sampling replicates in Maumere Bay, Sikka Regency, East Nusa Tenggara Province, Indonesia. The fishing gear used during sampling was a modified trammel net. The association between economically important fish with mangrove was analysed using Correspondence Analysis.

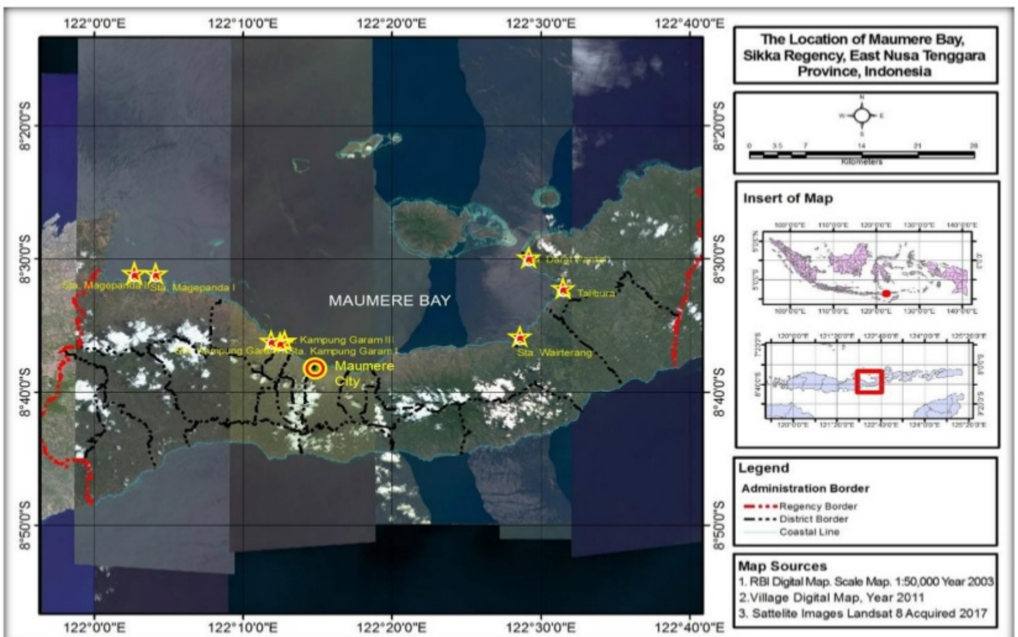

Figure 1. Map of the study area and sampling sites

2.1. Mangrove data collection procedures

Mangrove data collected consisted of spatial data (mangrove belt width and area, mangrove percentage cover) and non spatial data (mangrove density and dominance).

2.1.1. Satellite image data. Mangrove belt width and area were analysed using Landsat ETM 7 and Landsat OLI/TIRS satellite images from 2017. For mangrove coverage was used band composite RGB 4 – 5 – 3 for Landsat ETM 7, and RGB 5 – 6 – 4 for Landsat 8 false colour. Landsat TM data have seven spectral bands, with a spatial resolution of 30 m for bands 1-5 and 7. The Landsat ETM+ data have eight spectral bands with a spatial resolution of 30 m for bands 1-7. Similarly, the Landsat 8 data have nine spectral bands with a spatial resolution of 30 m for bands 1-7 and 9 [9].

These data were interpreted and supervised classification used to divide the mangrove areas into three classes of mangrove coverage: high density, medium density, low density. Interpretation and supervised classification produced a tentative map of mangrove coverage. We then conducted an assessment of the accuracy of mangrove coverage data followed by re-interpretation for several areas to improve accuracy. This ground truthing and re-interpretation process was repeated until the assessed accuracy was at least 75 %.

2.1.2. Transect line plot (quadrat transect method). The transect line plot (quadrat transect method) was used to collect in situ/non spatial mangrove data. Transect lines were set perpendicular to the coastline, with the transect length based on the width of the mangrove belt. Three quadrats (10x10 m plots) were placed along each transect line in three mangrove zones. At each station there were three transect lines and nine quadrats.

We collected the following mangrove data from each quadrat following [10]: mangrove tree diameter, species of mangrove and number of trees per species. Mangrove tree diameter was only measured for trees with a trunk diameter over 4 cm or circumference of over 16 cm [11]. Tree trunk diameter at breast height (DBH) was measured using a tape measure at 1.3 metres above the substrate surface [12,13]. Mangrove species were identified using mangrove identification guides [14–16].

Mangrove data were analysed to determine the frequency value of each species (F_i), species density (SD_i) and species dominancy (SD_i). Species frequency (F_i) is the probability that the i[th] species would be found in any particular quadrat, and was calculated using the formula [12]:

$$F_i = p_i / \Sigma p \quad (1)$$

where : F_i = Frequency of the i^{th} species
p_i = Number of plots where the i^{th} species was found
Σp = Total number of quadrats

Species density (Di) is the number of the ith species per unit area [12], with the formula :

$$D_i = \frac{n_i}{A} \quad (2)$$

where : D_i = i^{th} species density (number of the i^{th} species/Ha)
n_i = Total number of the ith species
A = Total sampling area (hectare).

The dominancy of the i^{th} species (C_i) is the basal area of the i^{th} species in particular area unit (m^2/ha) [12]. Species dominancy was calculated according to English et al [12] and Kusmana [13]:

$$C_i = \frac{\Sigma BA}{A} \quad (3)$$

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$$BA = \pi R^2 \quad \text{or} \quad BA = \tfrac{1}{4} \pi D^2 \quad \text{or} \quad \pi (DBH)^2/4 \qquad (4)$$
4

where : C_i = Dominancy of ith species (m^2/Ha)
BA = Basal Area (calculated for each tree of the i^{th} species)
A = Total plot area (Ha)
π = constant ≈3.1416
R = radius of tree
D = diameter of tree
DBH = Diameter at breast height.

2.2. Sampling and data analysis of fish.

Sampling of mangrove-associated fishes (species assemblages) was conducted at 8 stations (7 station of mangrove area, 1 station in a non-mangrove area) with three sampling point at each station. Sampling for collecting fish data was conducted over 8 months (September 2017 to April 2018).

The fishing gear used for collecting fish was a modified trammel net (net with three layers) with a length of 40 m, height of 180 cm, 1.5 inch mesh size for each layer. The middle of layer used nylon monofilament number 80, the outer layer was nylon multifilament type D9. Floats were attached to the top line (50 x Y-3 type units) and weights were attached to the bottom line (100 x 25 gr units). Two 3 kg anchors were uses to anchor the bottom end of the net. Buoys (2 x 30 cm diameter floats) were attached to the ends of the upper edge of the net.

The modified trammel net was set in the mangrove areas, close to river estuaries. The nets were set in the late evening (19.00 – 20.00) and left overnight. Hauling took place in the early morning (04.00 – 05.00).

2.3. Data analysis

Mangrove data was analysed using software developed for Monitoring Mangrove Degradation/Health (Dharmawan, 2014). Fish assemblage and mangrove data were analysed using the Analysis of Similarities (ANOSIM) functionality in PRIMER 5 version 5.2.2. The correlation between mangrove and fish variables was determined using Correspondence Analysis.

3. Results and Discussion

3.1. Mangrove diversity at Maumere Bay.

Mangroves in Maumere Bay, Sikka Regency are concentrated in four areas: the western area of Sikka Regency, Kampung Garam and surrounding areas, the eastern area of Sikka Regency, and the small islands of Sikka Regency [17]. The seven study sites were selected to represent these areas. A synopsis of the mangrove diversity data is shown in Table 1.

Table 1. Mangrove diversity at seven stations in Maumere Bay

Number	Stations / substations	Area (Ha)	Belt width (m)	Mangrove cover (%)	Density (trees/Ha)	Dominance (m^2/Ha)
1.	Darat Pantai	*133.43*			*3,220*	*35.46*
	1. Mageroneng	32.53	149.32	83.57	3,183	37.19
	2. Padubima	19.90	115.21	65.04	3,467	36.55
	3. Wairwua	81.00	213.35	77.48	2,800	29.83
2.	Talibura			*80.63*		
	1. North	3.43	89.69	80.55	2,467	30.38
	2. Centre	7.29	140.90	81.28	2,367	31.24
	3. South	7.84	153.53	80.08	2,267	28.97

Number	Stations / substations	Area (Ha)	Belt width (m)	Mangrove cover (%)	Density (trees/Ha)	Dominance (m^2/Ha)
3.	Kampung Garam I			*59.00*		*25.89*
	1. East	5.17	130.44	55.35	2,433	26.34
	2. Centre	8.50	277.61	59.92	1,633	26.64
	3. West	8.93	385.41	61.72	2,400	24.67
4.	Kampung Garam II/Wuring		*427.61*			
	1. East	19.09	335.87	59.07	2,833	28.06
	2. Centre	12.42	219.33	63.35	2,433	22.34
	3. West	16.18	727.63	73.75	3,600	31.18
5.	Kampung Garam III/ Wuring Leko					
	1. North	11.72	427.93	65.61	2,933	30.31
	2. Centre	7.41	381.32	56.87	3,033	32.04
	3. South	6.23	253.74	57.78	2,300	17.48
6.	Magepanda I/Fata	*18.37*			*2,333*	
	1. East	5.76	208.42	80.89	2,667	32.70
	2. Centre	5.77	197.31	83.49	2,200	30.41
	3. West	6.85	160.56	66.86	2,133	23.92
7.	Magepanda II/Ndete		*114.74*			
	1. North	11.02	64.47	75.40	2,500	31.96
	2. Centre	43.59	146.19	30.68	2,567	28.94
	3. South	1.17	133.56	94.38	2,167	23.91

The results in terms of mangrove area indicate that human activity has adversely affected mangrove extent. This is supported by [1] who found that mangrove loss has been driven in large part by conversion to other uses, often justified based on incomplete economic arguments and short time horizons. Table 1 shows that the highest of mangrove area was found at Darat Pantai station accounting for 133.43 Ha (total area of three substations). The smallest mangrove area was at Magepanda I/Fata station (18.37 ha) where most mangrove forests had been converted to brackishwater ponds or cleared for residential use.

The widest mangrove belt was found at Kampung Garam II/Wuring (mean 427.6 m), and the narrowest at Magepanda II/Ndete (mean 114.7m). The results indicate that mangrove belt width was influenced by the distance from the coastline to the mainland. Kampung Garam II/Wuring station was located in the bay where access to the location was limited.

The highest percentage of mangrove cover was found at Talibura station (80.63%) and the lowest at Kampung Garam I (59.00%). The results indicate that the percentage of mangrove canopy cover was closely related to mangrove density. At Talibura station, mangrove canopy was quite dense, because there was a village regulation in Talibura that prohibited the cutting of mangrove trees by the community. The local regulation was well implemented and there was increasing public awareness regarding the importance of protecting the mangrove area [18]. Hutchinson [1] mentioned that avoidance of mangrove loss is most effectively achieved through protective regulation(s) and/or the development of strong local or community level ownership.

Mangrove density and dominance indices were calculated based on 8 species of mangrove: (i) *Avicennia alba*, BL., (ii) *Avicennia marina*, (Forsk). Vierh, (iii) *Bruguiera gymnorrhiza*, (L.) Lamk, (iv) *Bruguiera parviflora*, (Roxb.) W.&A. ex Grift. (v) *Ceriops tagal*, (Perr.) C.B. Rob, (vi) *Rhizophora apiculata*, BL., (vii) *Rhizophora mucronata*, Lmk., (viii) *Sonneratia alba*, J.E. Smith. The highest average mangrove density was found at Darat Pantai station (3,220 tree/ha), and the lowest (2,333 tree/ha) at Magepanda I/Fata station. The results confirmed the impact of human activity on mangroves, specifically in terms of density. Forest degradation and loss of habitat connectivity may reduce the protective capacity of mangroves [5]. Darat Pantai station was located quite far from the

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city with less pressure from human activities, consequently mangroves were mostly allowed to grow naturally [17].

The highest average mangrove dominancy index was 35.46 m^2/ha at Darat Pantai station. Mangrove dominance is determined based on the basal area of mangrove trees [13]. The mangroves at Darat Pantai had large tree trunks with the widest mean diameter.

3.2. Fish Assemblages at Maumere Bay.

During this study, 38 species of fish were caught in the experimental fishing gear. These fishes belonged to 36 genera and 30 families (Table 2).

Table 2. Biodiversity and abundance fish assemblages at the 7 sampling stations in the study area

No	Species	Genus	Family	Darat Pantai	Talibura	Kampung Garam I	Kampung Garam II/ Wuring	Kampung Garam III/ Wuring Leko	Magepanda I/ Fata	Magepanda II/ Ndete
1	*Upeneus moluccensis*, Bleeker 1855	*Upeneus*	Mullidae	33	19	11	29	26	9	8
2	*Epinephelus fuscoguttatus*, Forsskål 1775	*Epinephelus*	Serranidae	8	8	3	3	2	2	1
3	*Cromileptes altivelis*, Valenciennes 1828	*Cromileptes*	Serranidae	2	3	0	6	4	0	5
4	*Lates calcarifer*, Bloch 1790	*Lates*	Latidae	6	1	5	1	1	1	0
5	*Psammoperca waigiensis*, Cuvier 1828	*Psammoperca*	Latidae	5	0	3	3	3	8	7
6	*Lutjanus bitaeniatus*, Valenciennes 1830	*Lutjanus*	Lutjanidae	9	3	0	5	2	2	8
7	*Lutjanus johnii*, Bloch 1792	*Lutjanus*	Lutjanidae	3	6	5	6	9	1	2
8	*Pristipomoides filamentosus*, Valenciennes 1830	*Pristipomoides*	Lutjanidae	4	7	0	8	3	9	7
9	Siganus canaliculatus, Park 1797	*Siganus*	Siganidae	11	7	16	17	17	12	15
10	*Siganus javus*, Linnaeus 1766	*Siganus*	Siganidae	5	5	21	16	12	4	1
11	*Taeniura lymma*, Forsskål 1775	*Taeniura*	Dasyatidae	3	3	1	4	1	11	4
12	*Neotrygon annotata*, Last 1987	*Neotrygon*	Dasyatidae	0	0	0	0	0	2	3
13	*Stegostoma fasciatum*, Hermann 1783	*Stegostoma*	Stegostomatidae	10	0	19	28	25	0	2
14	*Achiroides leucorhynchos*, Bleeker 1851	*Achiroides*	Soleidae	38	16	27	28	27	28	9
15	*Synanceia verrucosa*, Bloch &Schneider 1801	*Synanceia*	Synanceiidae	11	8	14	10	4	10	13
16	*Aluterus monoceros*, Linnaeus 1758	*Aluterus*	Monacanthidae	33	12	14	13	21	25	12
17	*Carangoides malabaricus*,	*Carangoides*	Carangidae	9	11	16	21	17	9	4

No	Species	Genus	Family	Darat Pantai	Talibura	Kampung Garam I	Kampung Garam II/ Wuring	Kampung Garam III/ Wuring Leko	Magepanda I/ Fata	Magepanda II/ Ndete
	Bloch&Schneider1801									
18	*Nemipterus nematophorus*, Bleeker 1854	*Nemipterus*	Nemipteridae	5	15	2	9	8	5	5
19	*Lethrinus lentjan*, Lacepède 1802	*Lethrinus*	Lethrinidae	13	12	7	9	12	5	14
20	*Euristhmus microceps*, Richardson 1845	*Euristhmus*	Plotosidae	25	20	16	12	17	10	15
21	*Onigocia macrolepis*, Bleeker 1854	*Onigocia*	Platycephalidae	11	4	0	7	4	1	3
22	*Pomadasys maculatus*, Bloch 1793	*Pomadasys*	Haemulidae	20	8	9	9	5	12	9
23	*Scarus frenatus*, Lacepède 1802	*Scarus*	Scaridae	27	10	2	3	0	0	2
24	*Myripristis hexagona*, Lacepède 1802	*Myripristis*	Holocentridae	2	2	4	1	8	3	0
25	*Saurida tumbil*, Bloch 1795	*Saurida*	Synodontidae	0	5	5	1	0	5	0
26	*Priacanthus macracanthus*, Cuvier 1829	*Priacanthus*	Priacanthidae	4	2	19	7	12	4	6
27	*Helotes sexlineatus*, Quoy & Gaimard 1825	*Helotes*	Terapontidae	9	4	5	9	12	4	4
28	*Chanos chanos*, Forsskål 1775	*Chanos*	Chanidae	9	5	13	23	13	4	7
29	*Mugil cephalus*, Linnaeus 1758	*Mugil*	Mugilidae	11	4	20	8	13	0	5
30	*Arothron caeruleopunctatus*, Matsuura 1994	*Arothron*	Tetraodontidae	16	6	16	11	14	9	10
31	*Platax teira*, Forsskål 1775	*Platax*	Ephippidae	0	0	0	10	4	0	0
32	*Hippocampus denise*, Lourie & Randall 2003	*Hippocampus*	Syngnathidae	2	0	2	2	2	3	0
33	*Syngnathoides biaculeatus*, Bloch 1785	*Syngnathoides*	Syngnathidae	2	0	4	3	3	0	2
34	*Scylla serrata*, Forsskål 1775	*Scylla*	Portunidae	63	28	60	87	78	42	53
35	*Portunus pelagicus*, Linnaeus 1758	*Portunus*	Portunidae	22	18	23	31	20	9	8
36	*Penaeus merguensis*, de Man	*Penaeus*	Penaeidae	4	4	6	0	2	0	6
37	*Panulirus versicolor*, Latreille 1804	*Panulirus*	Palinuridae	0	3	1	2	4	5	6
38	*Octopus vulgaris*, Leach 1818	*Octopus*	Octopodidae	0	1	0	2	1	7	9

The results indicate a strong correlation between the number of fish species and mangrove condition. Darat Pantai station, which had the highest mangrove area, density and dominance also had the highest number of fish species. The eleven species found at this site were: *Upeneus moluccensis, Epinephelus fuscoguttatus, Lates calcarifer, Lutjanus bitaeniatus, Achiroides leucorhynchos, Synanceia verrucosa, Aluterus monoceros, Euristhmus microceps, Pomadasys maculatus, Scarus frenatus,* and *Arothron caeruleopunctatus*. This finding is similar to the results of [1] who found that fish productivity will increase with an increase in total area of mangroves.

Interestingly, we found that the area with the highest mangrove cover at Talibura station could be the best habitat for three fish species: *Epinephelus fuscoguttatus, Nemipterus nematophorus*, and *Saurida tumbil* (Table 2). The site with the highest belt width of mangrove, Kampung Garam II/Wuring, provided habitat for 8 species: *Cromileptes altivelis, Siganus canaliculatus, Stegostoma fasciatum, Carangoides malabaricus, Chanos chanos, Platax teira, Scylla serrata,* and *Portunus pelagicus*.

3.3. *Economically important fish species*

Of the 38 fish species found at the 7 mangrove sampling stations, 20 species were economically important fishes. These were: *Upeneus moluccensis* Bleeker 1855 (Figure 2), (2) *Epinephelus fuscoguttatus* Forsskål 1775, (3) *Cromileptes altivelis* Valenciennes 1828, (4) *Lates calcarifer* Bloch 1790, (5) *Psammoperca waigiensis* Cuvier 1828, (6) *Lutjanus bitaeniatus* Valenciennes 1830, (7) *Siganus canaliculatus* Park 1797, (8) *Siganus javus* Linnaeus 1766, (9) *Stegostoma fasciatum* Hermann 1783 (Figure 3), (10) *Synanceia verrucosa* Bloch & Schneider 1801, (11) *Carangoides malabaricus* Bloch & Schneider 1801, (12) *Lethrinus lentjan* Lacepède 1802, (13) *Pomadasys maculatus* Bloch 1793, (14) *Scarus frenatus* Lacepède 1802, (15) *Chanos chanos* Forsskål 1775, (16) *Mugil cephalus* Linnaeus 1758, (17) *Scylla serrata* Forsskål 1775, (18) *Portunus pelagicus* Linnaeus 1758, (19) *Penaeus merguiensis* De Man 1907, and (20) *Panulirus versicolor* Latreille 1804.

Figure 2. *Upeneus moluccensis*

Figure 3. *Stegostoma fasciatum*

The correspondence analysis (Figure 4) indicated that mangrove locations characterised by dominant mangrove species *Bruguiera parviflora*, *Avicennia alba*, *Bruguiera gymnorrhiza*, *Ceriops tagal*, moderate values of the Shannon diversity index (1 <H '≤ 3), and moderate values of the Simpson dominance index (0.5 <C ≤ 0.75) were associated with the economically important fish species *Psammoperca waigiensis*, *Synanceia verrucosa* and *Pomadasys maculatus*. This association was thought to be influenced by the role of *Bruguiera parviflora* and *Avicennia alba* in reducing current velocity with a dense root system which provided habitat favoured by *Psammoperca waigiensis*. *Pomadasys maculatus*. These two fishes area generally found in coastal waters, seeking crustaceans and small fish as food.

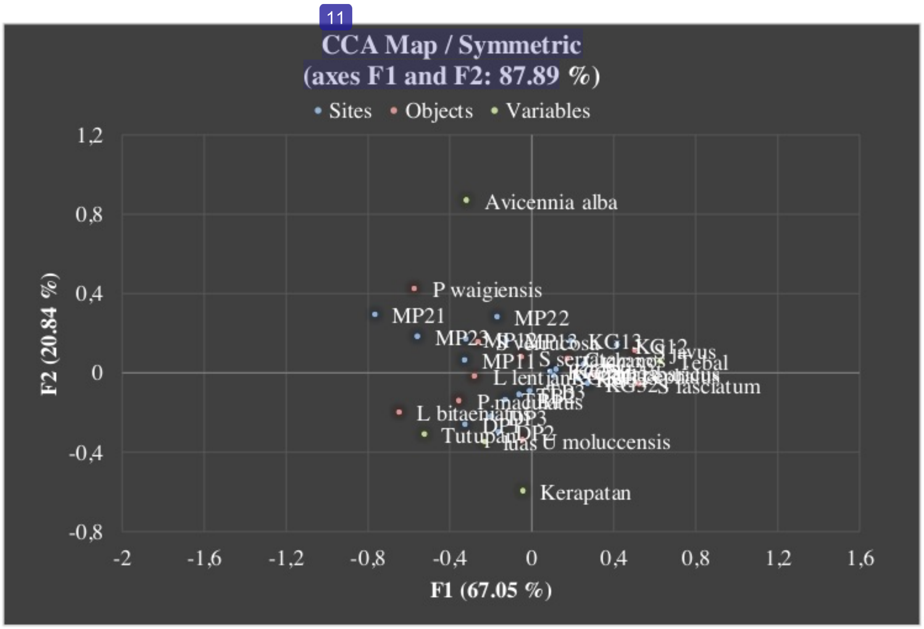

Figure 4. Correspondence analysis output showing correlations between mangrove parameters and the presence of economically important fish species

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The mangrove locations with high mangrove cover (≥ 80%), *Avicennia marina* dominancy, large area (> 100 ha) and high density (≥ 3000 trees/ha), *Rhizophora mucronata* dominancy, and high value of Pielou's evenness index (0.6 < E ≤ 1.0) were associated with the economically important fish species *Upeneus mollucensis*, *Lethrinus lentjan*, and *Lutjanus bitaeniatus*. These are fish which can grow to large sizes. They can adapt to faster current velocities, and are known to search for food in mangrove habitat.

The mangrove locations with medium cover (50% - 75%), moderate values of the Simpson dominance index (0.5 < C ≤ 0.75) and high mangrove belt width (≥ 400 m) were associated with the economically important fish species *Siganus javus*, *Stegostoma fasciatum*, *Mugil cephalus*, *Carangoides malabaricus* and *Chanos chanos*. *Siganus javus* and *Stegostoma fasciatum* are not mangrove resident species, being more typically found in seagrass areas. The associations that occurred here were most likely influenced by the physical condition of the mangroves which were not too dense, so that they could provide suitable habitat for these fishes.

4. Conclusion
This study found associations between economically important fish and mangrove characteristics. The fish species present were influenced by the condition of the mangroves and the environmental characteristics. Fish were found in areas where the conditions were likely to guarantee the availability of suitable food and habitat suited to their size, swimming ability and behaviour.

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