IOP Conference Series: Earth and Environmental Science

PAPER • **OPEN ACCESS**

Complex Relationship Between Mangrove Ecosystem Variables and Fish Assemblages at Maumere Bay, Indonesia

To cite this article: A Vincentius *et al* 2019 *IOP Conf. Ser.: Earth Environ. Sci.* **253** 012035

View the article online for updates and enhancements.

This content was downloaded from IP address 59.127.168.43 on 09/10/2019 at 17:27

IOP Conf. Series: Earth and Environmental Science **253** (2019) 012035 doi:10.1088/1755-1315/253/1/012035

Complex Relationship Between Mangrove Ecosystem Variables and Fish Assemblages at Maumere Bay, Indonesia

A Vincentius[1], M N Nessa[2], J Jompa[2] and A Saru[2]

[1] Marine Science and Fisheries Faculty, Nusa Nipa University, Jl. Kesehatan 3, Maumere, Flores 86111, East Nusa Tenggara, Indonesia.
[2] Marine Science and Fisheries Faculty, Universitas Hasanuddin, Jl. Perintis Kemerdekaan 10, Makassar 90245, Indonesia

Email: angelinusvincentiustonda@gmail.com

Abstract. The aim of this study was to examine the abundance and composition of fish assemblages in the mangrove ecosystems of Maumere Bay, Indonesia. The study was conducted from September 2017 – April 2018. Sampling was conducted at 7 stations, with three substations as sampling replicates. Mangrove condition variables were mangrove area and belt width, mangrove percentage cover, mangrove density and dominance. Fish community variables were the abundance of each fish species and taxonomic fish diversity. Mangrove condition variables were collected and analysed using spatial analysis and quadrat transect methods. Data on fish assemblages caught by three-layer trammel nets were analysed using PRIMER, to obtain similarity percentages, ANOSIM and nMDS plots. To determine the correlation between mangrove and fish variables, data was analysed by multivariate regression using XLSTAT software. Results showed that overall 38 species of fish were recorded, belonging to 36 genera and 30 families. Darat Pantai station had the highest area (134.35 Ha), mangrove density (3,220 trees/Ha), and dominance (35.46 m^2/ha), while Talibura station had the highest percentage mangrove cover (80.63%) and the highest mangrove belt width was found at Kampung Garam II/Wuring station (427.6 m). The analysis of similarities (ANOSIM) at significance level 0.1% showed significant between-site differences in both mangrove assemblage structure and fish assemblages. The highest similarity percentage for mangroves was at Talibura station (98.53%), and for fish assemblages at Kampung Garam II/Wuring station (46.91%). Multivariate regression analysis showed that two mangrove ecosystem variables, belt width and density, were positively correlated with fish assemblage abundance and diversity, the strongest correlation (R^2 = 0.279) being with mangrove belt width.

1. Introduction

Mangrove ecosystems provide ecosystem services of importance for both commercial and subsistence fisheries, functioning as spawning grounds, feeding grounds and nursery grounds for a diverse array of species including finfish, shellfish and crustaceans [1][2]. Research on the connection between mangrove ecosystem and fisheries production has found that mangrove ecosystems were linked to and supported fisheries production [3][4][5][6][7]. As an example, in Northeastern Australia such links were evident for banana prawns, (*Penaeus merguiensis*), mud crabs (*Scylla serrata*), barramundi (*Lates calcarifer*), and several estuarine species (*Penaeus esculentus*, *Penaeus semisulcatus*, *Portunus pelagicus*, *Eleutheronema tetradactylum*) [3]. In the Caribbean, the biomass of several coral fishes has been reported to increase two fold when mangrove ecosystems are present [4]. In California Bay, it

Content from this work may be used under the terms of the Creative Commons Attribution 3.0 licence. Any further distribution of this work must maintain attribution to the author(s) and the title of the work, journal citation and DOI.
Published under licence by IOP Publishing Ltd

was found that catch fish production increased with mangrove abundance [5], with a correlation between mangrove forests and artisanal fisheries catch in the southern part of the Bay [6]. Similarly, in Indonesia a positive correlation was found between mangrove density and fish diversity in Kulisusu Bay, North Buton Regency, Southeast Sulawesi [7].

It has been suggested [8] that changes in mangrove, density, found to cause changes in mangrove vegetation assemblages and composition, would affect assemblages of organisms associated with mangrove ecosystems. Leaf litter produced by mangroves is important in organic matter transfer between plants and soil. Nutrients and detritus released from this leaf litter through decomposition play an important role in supporting mangrove growth and providing food for many aquatic organisms in both marine and estuarine ecosystems [10]. Thus, leaf litter and other organic matter from mangroves supply nutrients which are key factors in determining marine fisheries productivity [11].

Most studies to date have focused on the correlation between one or two mangrove variables and fisheries production, however there is a lack of multivariate studies exploring the connections between a range of mangrove ecosystem and fish assemblage variables. This study aimed to analyse fisheries variables (the abundance of each fish species and taxonomic fish diversity) that could be affected by mangrove variables (mangrove belt width and area, mangrove percentage cover, mangrove density and dominance), to examine correlation patterns between mangrove and fish variables, and to determine which variable(s) were most influential based on the strength of the observed correlations.

2. Materials and Methods

2.1. Study site

This research was conducted in Maumere Bay, Sikka Regency, East Nusa Tenggara Province, Indonesia. Sikka Regency is located in the central area of Flores Island, with Maumere as capital city (Figure 1). The local names of the seven mangrove study sites or stations were (1) Darat Pantai, (2) Talibura, (3) Kampung Garam I, (4) Kampung Garam II/Wuring, (5) Kampung Garam III/Wuring Leko, (6) Magepanda I/Fata, (7) Magepanda II/Ndete, while one station (Wairterang) was in a non-mangrove area.

2.2. Mangrove sampling and data analysis

2.2.1. Spatial analysis

Mangrove area and belt width were determined through the analysis of satellite images Landsat ETM 7 and Landsat OLI/TIRS from 2017. Landsat ETM 7 data are comprised of eight spectral bands with a spatial resolution of 30 m for bands 1-7, while Landsat 8 data have nine spectral bands with a spatial resolution of 30 m for bands 1-7 and 9 [12]. Mangrove coverage used false colour composites of bands RGB 4 – 5 – 3 for Landsat ETM 7, and RGB 5 – 6 – 4 for Landsat 8.

The data were interpreted and supervised classification was used to separate the mangrove class into three mangrove coverage classes: high density, medium density, low density, producing a tentative map of mangrove coverage, and an average percentage cover for each station and site. This was followed by an initial assessment and ground-truthing with re-interpretation until a mangrove cover classification accuracy ≥ 75 % was attained.

2.2.2. Quadrat transects

The quadrat transect method was used to collect *in situ*/non spatial mangrove data. Transect lines were placed perpendicular to the coastline, with the line length based on the mangrove belt width. Three 10x10 m^2 quadrat plots along each transect line [13] were placed in order to sample the three mangrove zones. At each station sampling comprised three transect lines and nine quadrats. Mangrove data collected from each quadrat (10x10 m^2) included: mangrove tree diameter, mangrove species, and number of trees per species [14].

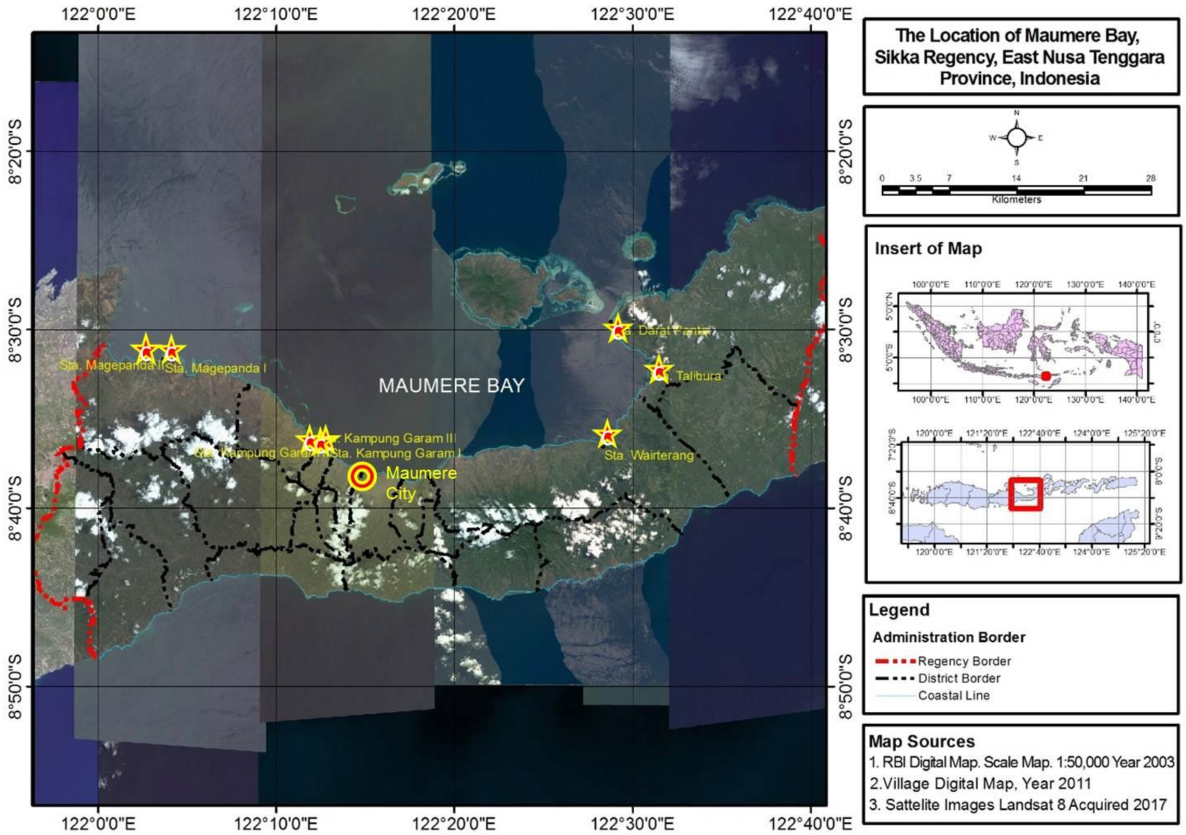

Figure 1. Map of the study area showing the sampling stations (stars = study sites)

Mangrove tree diameter at breast height (DBH) was measured 1.3 meter from the soil surface, for trees where the trunk diameter > 4 cm or trunk circumference > 16 cm [10], using a tape measure [13][15]. Mangrove species was identified using mangrove identification guidebooks [16][17][18].

Mangrove data were analysed to determine species frequency (F_i) , the probability of finding the i^{th} species in a quadratic plot; species density (SD_i), the number of the i^{th} species per unit area; and species dominancy (SD_i), the basal area of particular species in particular area unit (m2/ha). These indices were calculated according to the following formulae [13]

$$F_i = p_i \cdot (\Sigma p)^{-1} \quad (1)$$

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 (plots).

$$D_i = n_i \,.\, A^{-1} \quad (2)$$

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

$$C_i = \Sigma\, BA \cdot A^{-1} \quad (3)$$

$$BA = \tfrac{1}{4}\, \pi\, (DBH)^2 \quad (4)$$

where: C_i = Dominancy of the i^{th} species (m^2/Ha)

BA = Basal Area
A = Total width area of plot (Ha)
π = constant ≈ 3.1416
DBH = tree trunk diameter at breast height.

2.3. Fish sampling
Sampling of fish species assemblages was conducted at three sampling points within each of the 8 stations (Figure 1), of which seven stations were in mangrove areas and one station was in a non-mangrove area. Sample collection took place over 8 months (September 2017 to April 2018) using a modified three layer trammel net. The net was 40 m long x 180 cm high, with a mesh size of 1.5". The middle layer was made from number 80 monofilament net, and the outer layers from nylon multifilament net of type D9. Floats were attached to the top line (50 units, type Y-3) and sinkers (weights) to the bottom line (100 units, 25 g ea.). Two 3kg anchors were attached to the bottom edge of the net, one at each end, with buoys (30cm diameter) at each end of the upper edge. This modified trammel net was set at night (19:00 – 20:00) with hauling in the early morning (04:00 – 05:00). All fish caught were identified to species level, and the data tabulated by taxon and station.

2.4. Data analysis
Mangrove data were analysed using software for Monitoring Mangrove Degradation/Health developed by Dharmawan [19]. Fish and mangrove assemblages were analysed in PRIMER 5 version 5.2.2, using the Analysis of Similarities (ANOSIM), Similarity Percentages (SIMPER) and Non Multidimensional Scaling (nMDS) plot functions. The correlations between mangrove and fish variables were determined using multivariate regression analysis performed in SPSS version 15.0.

3. Results and Discussion

3.1. Mangrove diversity at Maumere Bay
Mangrove ecosystems in Maumere Bay, Sikka Regency are concentrated in four main areas: western Sikka Regency; Kampung Garam and surrounding areas; eastern Sikka Regency; and the small islands of Sikka Regency [20]. The 7 mangrove study sites were selected as being representative of those four mangrove areas. Mangrove diversity data (Table 1) show that Darat Pantai station had the highest mangrove area, covering 133.43 Ha (total area of the three substations).

Table 1. Mangrove diversity at Maumere Bay

Number	Stations / substations (Abbreviation)	Area (Ha)	Belt width (m)	Mangrove cover (%)	Density (tree/Ha)	Dominance (m^2/Ha)
1.	Darat Pantai (DP)*	*133.43*	*159.29*	*75.37*	*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 (TB)*	*18.57*	*128.04*	*80.63*	*2,367*	*30.20*
	1. Northern	3.43	89.69	80.55	2,467	30.38
	2. Central	7.29	140.90	81.28	2,367	31.24
	3. Southern	7.84	153.53	80.08	2,267	28.97
3.	Kampung Garam I (KG1)*	*22.60*	*264.49*	*59.00*	*2,456*	*25.89*
	1. Eastern	5.17	130.44	55.35	2,433	26.34
	2. Central	8.50	277.61	59.92	1,633	26.64
	3. Western	8.93	385.41	61.72	2,400	24.67

Number	Stations / substations (Abbreviation)	Area (Ha)	Belt width (m)	Mangrove cover (%)	Density (tree/Ha)	Dominance (m^2/Ha)
4.	Kampung Garam II (Wuring)*	*47.69*	*427.61*	*65.39*	*2,956*	*27.19*
	1. Eastern	19.09	335.87	59.07	2,833	28.06
	2. Central	12.42	219.33	63.35	2,433	22.34
	3. Western	16.18	727.63	73.75	3,600	31.18
5.	Kampung Garam III Wuring Leko (Wr Leko)*	*25.37*	*354.33*	*60.08*	*2,756*	*26.61*
	1. Northern	11.72	427.93	65.61	2,933	30.31
	2. Central	7.41	381.32	56.87	3,033	32.04
	3. Southern	6.23	253.74	57.78	2,300	17.48
6.	Magepanda I (Fata)*	*18.37*	*188.76*	*77.08*	*2,333*	*29.01*
	1. Eastern	5.76	208.42	80.89	2,667	32.70
	2. Central	5.77	197.31	83.49	2,200	30.41
	3. Western	6.85	160.56	66.86	2,133	23.92
7.	Magepanda II (Ndete)*	*55.77*	*114.74*	*66.82*	*2,411*	*28.29*
	1. Northern	11.02	64.47	75.40	2,500	31.96
	2. Central	43.59	146.19	30.68	2,567	28.94
	3. Southern	1.17	133.56	94.38	2,167	23.91

* Total area of the three stations per site, and mean values of other parameters, in italics

The data in Table 1 indicate that the distance of mangroves from human activity affected the mangrove belt width. This finding is supported by a previous study [2] which 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. The lowest mangrove belt width was at Magepanda I/Fata (18.37 ha), where mangroves had been converted to brackishwater ponds and residential use.

The widest average mangrove belt width (427.61 m) was at Kampung Garam II/Wuring, and the narrowest at Magepanda II/Ndete, with indications that mangrove belt width is determined or limited by a combination of shoreline topography and human activity. Kampung Garam II/Wuring station is located in a bay with limited access. Furthermore, the highest mangrove percentage cover was found at Talibura station (80.63%) and the lowest percentage at Kampung Garam I (59%), indicating that the mangrove percentage cover was related to mangrove canopy density. Most mangrove trees at the Talibura station had a dense canopy due to a village regulation prohibiting the felling of mangrove trees by the community. The local regulation was implemented and there was increasing public awareness regarding the importance of protecting the mangrove area [21]. This is in line with the statement of Hutchinson [2] that avoidance of mangrove loss is most effectively achieved through protective regulations and/or the development of strong local/community level ownership.

Mangrove density and dominance were calculated for 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. Forest degradation and loss of habitat connectivity may reduce the protective capacity of mangroves [22], and the negative effects of human activity at most sites are reflected in the mangrove density results. 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 highest average mangrove dominance was 35.46 m^2/ha, also at Darat Pantai station, one reason for this being the large size and girth of the mangroves at this station. Darat Pantai is located far from the city with less pressure from human activities, enabling mangroves to grow naturally [20].

The ANOSIM analysis (Figure 2) showed a significant between station difference in species assemblages, with a significance level of 0.1% (P<0.01). The clear grouping of mangrove species assemblages by station shows that each station had its own typical mangrove community composition.

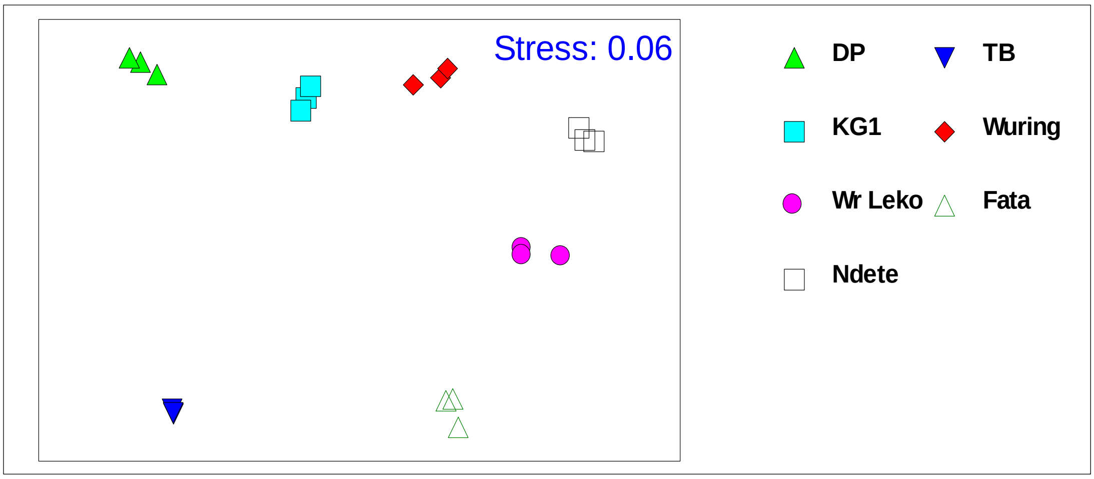

Figure 2. Non-metric Multi-Dimensional Scaling of mangrove assemblages in Maumere Bay.

The SIMPER (Similarity of Percentage) analysis showed clearly that there was high within station similarity but also generally low dissimilarity between stations. The highest similarity was found at Talibura (98.53%) and the lowest similarity was 93.21% at Kampung Garam II/Wuring. The lowest dissimilarity was 13.54% between Kampung Garam I and Kampung Garam II/Wuring and the species making the highest contribution (61.38%) to this dissimilarity was *Bruguiera gymnorrhisa*. Kampung Garam I and Kampung Garam II/Wuring are adjacent stations, with similar conditions in terms of temperature, depth, salinity, pH, dissolved oxygen, and substrate type.

3.2. Fish Assemblages at Maumere Bay

The fish sampled were identified as belonging to 38 species from 36 genera and 30 families (Table 2). The highest number of fish species (11) was recorded at Darat Pantai. These species were: *Upeneus moluccensis, Epinephelus fuscoguttatus, Lates calcarifer, Lutjanus bitaeniatus, Achiroides leucorhynchos, Synanceia verrucosa, Aluterus monoceros, Euristhmus microceps, Pomadasys maculatus, Scarus frenatus,* and *Arothron caeruleopunctatus*.

Table 2. Fish assemblages (species, genus, and family) sampled from 7 stations.

No.	Species	Genus	Family	Darat Pantai	Talibura	Kampung Garam I	Kampung Garam II/ i	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

No.	Species	Genus	Family	Darat Pantai	Talibura	Kampung Garam I	Kampung Garam II/ i	Kampung Garam III/ Wuring Leko	Magepanda I/ Fata	Magepanda II/ Ndete
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*, Bloch&Schneider1801	*Carangoides*	Carangidae	9	11	16	21	17	9	4
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 data in Table 2 indicate a relationship between number of fish species and mangrove condition and extent. This is in line with previous research findings that fish productivity will increase with an increase in total area of mangroves [2]. Darat Pantai, the station with the highest fish diversity, had the highest mangrove area, density and dominance. Interestingly, the station with the highest mangrove cover (Talibura) appears to provide the best habitat for three economically important fish species: *Epinephelus fuscoguttatus, Nemipterus nematophorus*, and *Saurida tumbil*. Kampung Garam II/Wuring, the station with the highest mangrove belt width, appears to provide habitat for at least 8 fisheries commodities, including the high value *Cromileptes altivelis* as well as *Siganus canaliculatus, Stegostoma fasciatum, Carangoides malabaricus, Chanos chanos, Platax teira, Scylla serrata,* and *Portunus pelagicus.*

The Non-metric Multi-Dimensional Scaling plot (Figure 3) showed no clear grouping of fish assemblages by station. This indicates similar assemblage structures across the study area. However the ANOSIM analysis did show a significant between station difference in species assemblages at significance level 99% (P<0.01). The Similarity percentages (SIMPER) analysis showed that Kampung Garam II/Wuring station had the highest average similarity (46.91%), indicating a correlation between mangrove belt width with species similarity at this station. Interestingly, the lowest similarity (32.90%) was between Talibura, the station with the highest of mangrove coverage, and the other stations; three species making the highest contribution to similarity were *Scylla serrata* (15.87%), *Upeneus moluccensis* (13.09%) and *Portunus pelagicus* (10.30%). The highest average dissimilarity (71.39%) was. between Talibura and Magepanda II/Ndete stations; three species making the highest contributions to the dissimilarity were *Scylla serrata* (6.73%), *Eurithmus microceps* (5.36%) and *Portunus pelagicus* (4.84%).

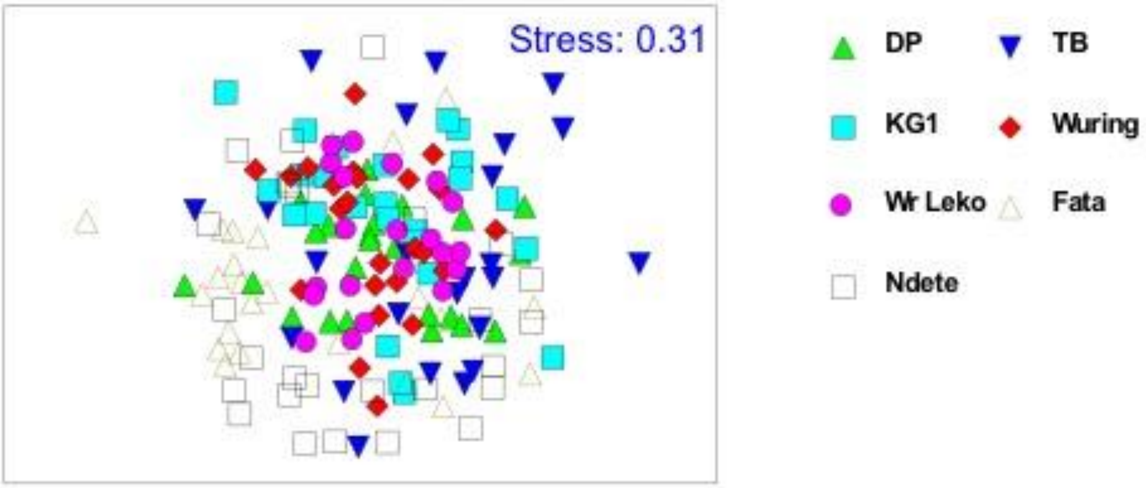

Figure 3. Non-metric Multi-Dimensional Scaling plot of fish at seven stations

The multivariate regression analysis of the correlation between mangrove and fish variables showed that two mangrove variables (belt width and density) had a correlation with fish assemblage. This is in line with previous studies [7][8] reporting significant effects of mangrove density on associated organism assemblages. Pearson's correlation post test showed the highest correlation (positive and statistically significant) was between mangrove belt width and fish assemblages, with regression equation $Y = 92.409 + 0,102\ X$ ($R^2 = 0.279$; r = 0.5282). The correlation coefficient *r* indicates that approximately half of the variability in mangrove fish assemblages could be predicted by mangrove belt width, and the equation predicts an increase of one fish species for each additional 10 m of mangrove belt width. This finding is similar to that of a review study focused on Queensland, Australia [23] which found a strong correlation between mangrove perimeter and fisheries production (fish, crab and shrimp).

4. Conclusions

Mangrove ecosystems play a crucial role in contributing to the production of fish. Mangrove variables, namely extent, belt width, mangrove coverage, density and dominance affected the abundance and composition of fish assemblages. Overall 8 species of mangrove and 38 species of fish were recorded during the study. Darat Pantai station had the highest mangrove area, density and dominance, while Talibura station had the highest mangrove cover and Kampung Garam II/Wuring station had the widest mangrove belt. There was a significant difference in mangrove and fish assemblages between stations. Mangrove area and density were positively correlated with fish assemblage abundance and diversity, however the correlation with area was stronger than with density. This result underlines the importance of scale (extent) as well as condition in mangrove ecosystem management.

Acknowledgements.
We would like to express our appreciation and gratitude to Nurjannah Nurdin from the Research and Development Center for Coastal Geospatial Planning, Hasanuddin University for providing spatial analysis laboratory facilities, and Sabinus Nabu from Nusa Nipa Foundation of Maumere for funding this research. We also wish to thank Nita Rukminasari and Abigail Moore for assistance with manuscript editing as well as all the technicians and local communities for their wonderful help during the fieldwork.

References

[1] Wafar S, Untawale A and Wafar M 1997 Litter fall and energy flux in a mangrove ecosystem *Est. Coast. Shelf. Sci.* **44** 111-124

[2] Hutchison J, Spalding M and Ermgassen P 2014 *The Role of mangroves in fisheries enhancement The Nature Conservancy and Wetlands* (International University of Cambridge United Kingdom)

[3] Manson F J, Loneragan N R Harch B D Skilleter G A Williams L 2005 A Broad-Scale Analysis of Links Between Coastal Fisheries Production and Mangrove Extent A Case-Study for Northeastern Australia *Fish. Res.* **74** 69–85

[4] Mumby P J 2006 Connectivity of Reef Fish Between Mangroves and Coral Reefs Algorithms for the Design of Marine Reserves at Seascape Scales *Biol. Conserv.* **128** 215-222

[5] Aburto-Oropeza O, Ezcurra E, Danemann G, Valdez V *et al* 2008 Mangroves in the Gulf of California Increase Fishery Yields *Proc. Natl. Acad. Sci.* **105** 10456–10459

[6] Carrasquilla-Henao M, Ocampo H A G, Gonzalez A L, Quiroz G R 2013 Mangrove Forest and Artisanal Fishery in the Southern Part of the Gulf of California Mexico *Ocean. Coast. Manage.* **83** 75-80

[7] Genisa A S 2006 Keanekaragaman Fauna Ikan di Perairan Mangrove Sungai Mahakam *Jurnal Oseanologi dan Limnologi Indonesia* **46** 39-51

[8] Dudi R, Tadjuddah M and Ramli M 2016 Keragaman mangrove terhadap sumber daya ikan pada ekosistem mangrove Teluk Kulisusu Kabupaten Buton Utara *Jurnal Manajemen Sumber Daya Perairan* **1** 367-375

[9] Mahmudi M 2010 Estimasi Produksi Ikan Melalui Nutrien Serasah Daun Mangrove di Kawasan Reboisasi *Rhizophora* Nguling Pasuruan Jawa Timur *Indonesian J. Mar. Sci.* **15** 231-235

[10] Ashton E C and Macintosh D J 2002 Preliminary assessment of the plant diversity and community ecology of the Sematan mangrove forest Sarawak Malaysia *Front. Ecol. Manag.* **166** 111-129

[11] Zamroni Y, Rohyani I S 2008 Produksi Serasah Hutan Mangrove di Perairan Pantai Teluk Sepi Lombok Barat *Biodiversitas* **4** 284-28

[12] Nurdin N, Komatsu T, Agus, Akbar A S M *et al* 2015 Multi sensor and multi temporal data from Landsat images to detect damage to coral reefs small islands in the Spermonde Archipelago Indonesia *Ocean. Sci. J.* **50** 317-325

[13] English S, Wilkinson C and Baker V 1997 *Survey Manual for Tropical Marine Resources* (Townsville: 2nd edition Australian Institute of Marine Science)

[14] Pramudji and Nontji A 2014 *Panduan Monitoring Status Ekosistem Mangrove CRITC COREMAP CTI LIPI* (Jakarta: Lembaga Ilmu Pengetahuan Indonesia Pusat Penelitian Oseanografi)

[15] Kusmana C 2017 *Metode Survey dan Interpretasi Data Vegetasi* (Bogor Agricultural University)

[16] Tomlinson, P B 1986 *The Botany of mangroves* (Cambridge U K: Cambridge University Press)

[17] Noor Y R, Khazali M, Suryadiputra I N N 2006 *Panduan Pengenalan Mangrove di Indonesia* (Bogor: Wetlands International Indonesia Programme dan Ditjen PHKA)

[18] Blaber S J M 2007 Mangroves and Fishes Issues of Diversity Dependence and Dogma *Bull. Mar. Sci.* **80** 457–472

[19] Giesen W, Wulffraat W S, Zieren M and Scholten L 2006 *Mangrove Guidebook for Southeast Asia* (Bangkok: FAO and Wetlands International)
[20] Dharmawan I W I and Pramudji 2014 *Guidelines Monitoring of Mangrove Ecosystem Status Research Centre for Oceanography Indonesian Institute of Sciences* (Jakarta)
[21] Vincentius A, Nessa M N, Jompa J, Saru A, Nurdin N and Rani C 2018 Influential factors analysis towards mangrove cover and production of demersal fish in Maumere Bay Indonesia *AACL Bioflux* **11** 810-822
[22] Lestari T A, Gumilang R S, Rahadian A, and Sualia I 2012 *Kajian Tingkat Kerentanan dan Kapasitas Masyarakat dalam rangka Pengurangan Resiko Bencana Studi Kasus Beberapa Desa di Kabupaten Sikka Kabupaten Ende dan Kota Serang* (Bogor: Wetlands International – Indonesia Programme)
[23] Lee S Y, Primavera J H, Dahdouh-Guebas F, McKee K *et al* 2014 Ecological role and services of tropical mangrove ecosystems a reassessment *Global. Ecol. Biogeogr.* **23** 726-743