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Crustacean and mollusk species diversity and abundance in the mangrove communities of Mimika District, Papua, Indonesia

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Abstract. Setyadi G, Rahayu DL, Pribadi R, Hartati R, Wijayanti DP, Sugianto DN, Darmawan A. 2021. Crustacean and mollusk species diversity and abundance in the mangrove communities of Mimika District, Papua, Indonesia. *Biodiversitas* 22: 4146-4157. A mangrove crustacean and mollusk species diversity study was carried out in four mangrove estuaries in Mimika District, Papua, Indonesia. Two locations were selected on each estuary; for each location, samples of crustaceans and mollusks were collected from 5 m × 5 m plots, and mangrove trees were recorded on 10 m × 10 m plots at a distance of 10 m, 250 m and 500 m perpendicular to the riverbank. This study recorded a total of 41 species of crustaceans and 32 species of mollusks the latter comprising three species of bivalves and 29 gastropod species. The number of crab species found was among the highest compared to similar studies in the world. The average number of species collected from each 25 m² plot was 7.6 ± 4.2 species for crustaceans, with an average abundance of 87 ± 3.5 individuals; for mollusks, it was 3.3 ± 3 species with an average abundance of 28 ± 48.4. Crustacean abundance and species composition were influenced by inundation frequency. There was a strong correlation between the crab *Parasesarma cricotum* and the association of *Rhizophora apiculata* and *Bruguiera gymnorhiza* mangroves, and *Clistoeloma amamaparens* and the association of *B. gymnorhiza*, *R. apiculata*, and *Bruguiera parviflora* mangroves. For mollusks, correlations were found between *Terebralia palustris* and *Ellobium aurisjudae* and the association of *R. apiculata* and *B. parviflora* mangroves. The highest crustacean Shannon-Wiener diversity index was associated with *Sonneratia alba* and *Avicennia marina* mangroves, and the highest mollusk Shannon-Wiener diversity index was associated with *R. apiculata* and *B. gymnorhiza* mangroves.

Keywords: Crustacean, diversity, mangrove, Mimika, mollusks, Papua

INTRODUCTION

Mangroves are highly productive coastal ecosystems with significant ecological and environmental value, providing habitats and nutrients for aquatic fauna and soil stabilization (El-Regal et al. 2014; Hogarth 2015). Mangrove vegetation contributes to faunal biodiversity (Ashton et al. 2003^a; Colpo et al. 2011).

Mangrove forests are populated by a variety of macroinvertebrates, such as brachyuran crabs, hermit crabs, gastropods, and bivalves. The most abundant, and the greatest biomass, is crustaceans, particularly true crabs (Hogarth 2015), which have various ecological roles and functions in the mangrove ecosystem and play a major role in the energy flow by exporting mangrove litter (Ngo-Massou et al. 2018). Crab burrows also allow seawater to penetrate and aerate the sediment and exchange nutrients (Ashton et al. 2003^a). Worldwide, more than 300 species of brachyuran crabs have been recorded in mangroves (Ravichandran et al. 2011). While there is limited information on brachyuran crabs in Indonesia, research in Peninsular and East Malaysia has found more than one

hundred brachyuran species inhabiting mangrove ecosystems (Tan and Ng 1994).

Mollusks typically snails comprise another dominant group in mangroves. Their distributions are affected by the extent of tidal exposure, substrate type, salinity and light intensity (Nagelkerken et al. 2008). The other group is bivalves (clams), which have high biomass and abundance. However, mangroves represent a harsh environment for bivalves due to the limited filter-feeding activity, while the distribution of their planktonic larvae is hampered by a lack of inundation (Zvonareva et al. 2009). 277 gastropod species have been recorded in mangrove ecosystems worldwide (Cantera et al. 1983), with the number of bivalves found in Indo-Pacific mangroves totaling 86 species (Morton 1983).

Papua is the eastern-most province in Indonesia and has one of the largest mangrove forests in the world. The total mangrove forest in Papua, Indonesia, was recently recorded at 1,497,724 hectares, or around 46% of the total mangrove forest in Indonesia, comprising 3.3 million ha (Setyadi et al. 2021). The majority of mangroves in Papua are found on the southern coast of Papua Island, including Mimika

district. All estuaries in Mimika District have mangroves, with an estimated area of 186,291 ha (Aslan et al. 2018), making it one of the least disturbed mangrove forests in Indonesia; nevertheless, there have been limited studies and international publications on this. Such a gap in the research represents an opportunity to explore the biodiversity of crabs and mollusks and to assess the correlation between the mangrove macro-invertebrate biodiversity and the mangrove community.

The main objective of this study is to determine the diversity, abundance and community structures of crustacean and mollusk macrofauna in the Mimika District of Papua, Indonesia. The other objective is to describe the correlation between crustacean and mollusk diversity and mangrove vegetation association as well as examine environmental factors such as inundation.

MATERIAL AND METHODS

Study area

The study was carried out from March to May, 2019, in four estuaries in the Mimika District, Papua Province, Indonesia. Papua Province is the eastern-most province in

Indonesia, located in Western New Guinea. Mimika District has the highest mountain on the Australia plate, with its highest peak at 3750 m. The Mimika coastal plains are characterized by extensive swampy areas spreading from the coast in a northeasterly direction, with mountains rising abruptly from the edge of the plains. The vast mangrove forests extend about 20 km inland, and have developed from the high sedimentation resulting from the combination of high rainfall of 4-13 m yr⁻¹, erosion from the rugged mountains, and 3.3 to 3.6 tidal ranges (Setyadi et al. 2009; Aslan et al. 2018).

The four estuaries were selected for the studies were the Kamora, Tipuka, Ajkwa and Minajerwi estuaries, whereby two sampling locations were selected for each estuary. These are shown in Figure 1, with detailed coordinates shown in Table 1. Kamora estuary has the highest catchment area of 1475 km² and an average river flow of 417 m³ s⁻¹. Tipuka has a catchment area of 178 km² and an average river flow of 41 m³ s⁻¹. Ajkwa has a catchment area of 270 km² and an average river flow of 115 100 m³ s⁻¹, and Minajerwi has a catchment area of 844 km² and an average river flow of 100 m³ s⁻¹ (PT Puri Fajar Mandiri 2002).

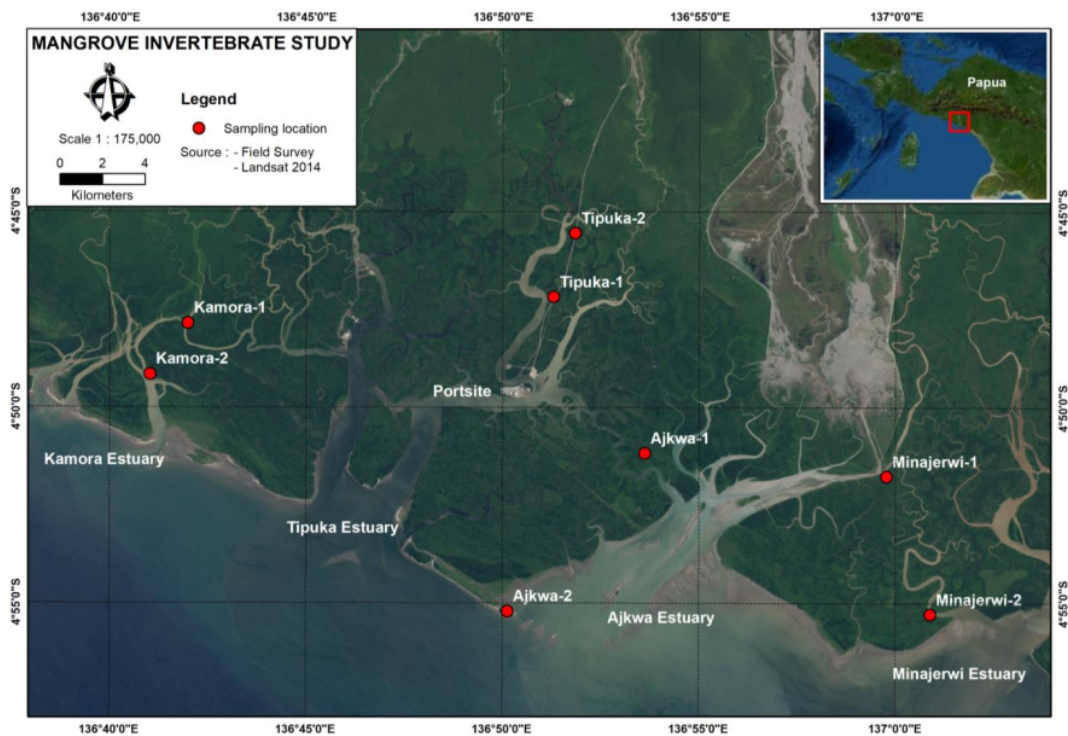


Figure 1. Study locations in Mimika District, Papua Province, Indonesia

Data collection

At each location, transects were established at distances of 10 m, 250 m and 500 m inland from the riverbank in the intertidal of the mangrove forest. At each distance, a 10 m x 10 m quadrat and three replicates were established, then the mangrove tree species, including the number for each species, were recorded. At each distance, crustaceans and mollusks were collected within 5 m x 5 m quadrats, with a total of three quadrats per location. The method was adopted from Ngo-Masou et al. (2018), but with larger quadrats. Sampling was carried out during the daytime at low tide. The collection process involved three people and included excavating burrows and removing all crabs and mollusks seen within each quadrat within the transect for about one hour until no more crabs or mollusks were visible. Hand trowels were used to excavate the crabs and bivalves from 10-20 cm deep burrows. All samples were put into labelled plastic bags and put in a cooler box with ice for transport to the laboratory. In the laboratory, mud was removed from all the specimens, and each specimen was preserved in a 70-75% solution of ethanol for later species identification. The identification of the crustaceans referred to Rahayu and Davie (2002; 2006), Rahayu and Takeda (2000), Rahayu and Setyadi (2009) and Li et al. (2018), whereas the identification of the mollusks referred to Carpenter and Niem (1998) and Setyadi et al. (2009).

The field parameters collected for each sampling plot were GPS coordinates, water temperature, salinity, and dissolved oxygen. Water parameters were collected from all ponding water and burrowing water found in the plot area.

Data analysis

For the mangrove tree data, the total number of species, density, and Shannon-Wiener index (H') and evenness (J') were calculated. The Shannon-Wiener index is commonly used to evaluate the diversity of mangrove species in Indonesia (Kasim et al. 2018; Sadono et al. 2020). Using PRIMER (2016), seven indices were calculated for crustaceans and mollusks: abundance, species richness (Margalef), Pielou's evenness, Shannon diversity, Simpson's dominance, Simpson's diversity and Simpson's dominance.

The Bray-Curtis similarity was calculated for the crustaceans and mollusk data, using the PRIMER software to determine the similarity between the sampling locations and between the plots. The relationships between the crustacean and mollusk species and the mangrove community types were analyzed using PCA (Principal Component Analysis) with PAST (Paleontological Statistics Software).

RESULTS AND DISCUSSIONS

Field parameters

The parameters measured in the field are shown on Table 1. The data show that the water temperature at all sampling locations ranged from 25.7 to 30.5 °C, salinity ranged from 0.28 to 25.7‰, pH ranged from 6.34 to 7.75, and dissolved oxygen ranged from 0.4 to 8.2 mg/L.

Mangrove trees

The species of mangrove trees from the eight locations are shown in Table 2. A total of 13 mangrove tree species were observed. The highest number of species (8) was found at Ajkwa-2. The most dominant mangrove tree species in all locations were *Rhizophora apiculata* and *Bruguiera gymnorrhiza*. *Avicennia marina* was only dominant at Ajkwa-2, which is located in the seaward zone of the high tidal area.

The lowest density was at Kamora-2 and the highest was at Ajkwa-2. The highest Shannon-Wiener index (H') was at Ajkwa-1 and the lowest was at Kamora-2, whereas the highest evenness (J') was at Ajkwa-1 and the lowest was at Minajerwi-2.

Species richness

A total of 41 species of crustacean and 32 species of mollusk were found in the study area (Table 1). The mollusks comprised three species of bivalves and 29 gastropods. The crab species recorded with the highest total abundance from all the plots was *Parasesarma indiarum* (785), followed by *Parasesarma cricatum* (280), *Sarmatium germaini* (232), *Clistoeloma amamaparens* (215) and *Sesarmoides borneensis* (107). For mollusks, the highest total abundance from all the plots was found for *Ellobium aurisjudae* (193) and *Terebralia palustris* (140).

The average number of species collected from each 25 m² plot for crustaceans was 7.6 ± 4.2 species and the average abundance was 87 ± 3.5 individuals. The highest species number recorded was from Ajkwa-2 at 250 m (16 species). Other high species numbers for collected crustaceans were found at Ajkwa-2 at 10 m (14 species), Kamora-1 at 10 m (14 species), and Kamora-1 at 500 m (14 species). The greatest abundance of collected crustaceans was at Ajkwa-2 at 10 m (251 individuals), followed by Ajkwa-2 at 500 m (243 individuals), Ajkwa-2 at 250 m (235 individuals), Kamora-1 at 500 m (223 individuals), and Kamora-1 at 10 m (144 individuals).

Table 1. Coordinates and field parameters taken from the sampling locations in Mimika District, Papua, Indonesia

Location	Coordinates		Temp (°C)	Salinity (‰)	pH	DO
	South	East				
Kamora 1	04°51'10.20"	136°53'36.82"	29.00 ± 0.44	7.63 ± 3.12	7.26 ± 0.02	2.40 ± 0.78
Kamora 2	04°51'45.63"	136°59'46.14"	28.53 ± 0.15	9.97 ± 1.42	6.55 ± 0.18	3.90 ± 2.00
Tipuka 1	04°55'12.08"	136°50'07.34"	29.30 ± 1.15	3.82 ± 0.87	7.32 ± 0.07	6.83 ± 0.50
Tipuka 2	04°55'17.18"	137°00'53.36"	28.87 ± 0.25	6.23 ± 0.92	7.19 ± 0.09	6.90 ± 0.17
Ajkwa 1	04°47'50.90"	136°41'58.92"	28.90 ± 0.40	11.60 ± 0.90	7.19 ± 0.02	7.20 ± 1.40
Ajkwa 2	04°49'09.17"	136°41'01.17"	26.70 ± 0.95	19.61 ± 5.41	7.56 ± 0.08	6.07 ± 0.35
Minajerwi 1	04°47'10.66"	136°51'17.21"	27.73 ± 0.57	0.43 ± 0.17	7.55 ± 0.17	6.60 ± 0.35
Minajerwi 2	04°45'32.67"	136°51'50.20"	27.10 ± 0.61	13.37 ± 1.96	7.26 ± 0.01	1.13 ± 0.64

Table 2. Vegetation data of Mimika District, Papua, Indonesia

Location	Mangrove Species	S	D	H'	J'
Kamora-1	Ra, Bg, Rm, Bp	4	722 ± 96	0.82 ± 0.16	0.86 ± 0.10
Kamora-2	Ra, Bp, Bg, Xg	4	666 ± 235	0.66 ± 0.15	0.70 ± 0.16
Tipuka-1	Ra, Xg, Bp, Bg	4	711 ± 107	1.07 ± 0.36	0.81 ± 0.19
Tipuka-2	Bg, Ra, Xg, Cs, Xm	5	878 ± 204	0.76 ± 0.52	0.49 ± 0.24
Ajkwa-1	Ra, Bg, Cs, Bp	4	767 ± 88	1.19 ± 0.14	0.92 ± 0.06
Ajkwa-2	Am, Bp, Sa, Ra, Ll, Ea, Nf, Bg	8	1089 ± 414	1.12 ± 0.47	0.80 ± 0.05
Minajerwi-1	Ra, Bg, Nf, Xg, Bp, Ba	6	944 ± 171	1.05 ± 0.09	0.83 ± 0.16
Minajerwi-2	Bg, Ra, Bp, Cs	4	756 ± 301	0.62 ± 0.09	0.47 ± 0.29

Note: S: Species Number; D: Density (tree ha⁻¹); H': Shannon-Weinner Index; J': Evenness Index; Ra: *Rhizophora apiculata*; Bg: *Bruguiera gymnorhiza*; Rm: *Rhizophora mucronata*; Bp: *Bruguiera parviflora*; Xg: *Xylocarpus granatum*; Cs: *Campostemon schultzei*; Xm: *Xylocarpus moluccensis*; Am: *Avicennia marina*; Sa: *Sonneratia alba*; Ll: *Lumnitzera littorea*; Ea: *Excoecaria agallocha*; Nf: *Nypa fruticans*; Ba: *Barringtonia asiatica*

Mollusks collected from each 25 m² plot had an average of 3.3 ± 3 species with an average abundance of 28 ± 48.4 . The highest species number recorded was from Minajerwi-1 at 250 m (11 species). Other high species numbers for collected mollusks were found at Minajerwi-1 at 10 m (9 species), Minajerwi-1 at 500 m (7 species), Ajkwa-2 at 10 m (7 species). The highest abundance of collected mollusks was at Ajkwa-2 at 10 m (179 individuals), followed by Ajkwa-2 at 250 m (158 individuals), Minajerwi-1 at 250 m (86 individuals), and Minajerwi-1 at 10 m (44 individuals).

The mollusk species recorded with the highest total abundance at all the plots were *Polymesoda expansa* (15 individuals) and *Isognomon ephippium* (13 individuals). For gastropods, the highest total abundance was *Ellobium aurisjudae* (193 individuals), followed by *Terebralia palustris* (140 individuals) and *Neritina violacea* (72 individuals). The most common species was *Nerita balteata* (found in 10 plots), followed by *E. aurisjudae*, *N. planospira*, and *N. violacea*, which were recorded in 6 plots each. There were 11 species of mollusk that found in one plot and 7 plots had no mollusk species.

The mean of species number, number of individuals, species richness, Shannon diversity index, evenness, and Simpson's dominance can be seen in Table 4. The highest species richness and Shannon diversity index for crustaceans was at Kamora-1 (2.46 ± 0.07 and 1.68 ± 0.13 respectively) and the lowest was Ajkwa-1 (0.80 ± 0.04 and 0.95 ± 0.48 , respectively). For mollusks, the highest species richness and Shannon diversity index were at Minajerwi-1 (1.93 ± 0.13 and 1.62 ± 0.42 , respectively).

The highest evenness index for crustaceans was found at Minajerwi-1 (0.94 ± 0.04), which is classified as high (Krebs 1989), and the lowest was at Ajkwa-2 (0.57 ± 0.12), which is classified as medium. The highest Shannon dominance was found at Tipuka-2 (0.55 ± 0.34) and the lowest was at Minajerwi-2 (0.31 ± 0.06). For mollusks, the highest evenness index was at Kamora-1 (0.86 ± 0.12), which is classified as high. The highest Shannon dominance was at Ajkwa-1 (0.67 ± 0.22).

Similarity

The Bray-Curtis similarity among the sampling locations was calculated using PRIMER. The Bray-Curtis

analysis, which is based on the similarity percentage of abundance for mangrove species, is shown on Figure 2. Based on the analysis, the mangroves from the study locations can be grouped into eight clusters: A. Association of *S. alba* and *A. marina* (Ajkwa-2B); B. Association of *A. marina*, *S. alba*, *B. parviflora* and *R. apiculata* (Ajkwa-2A and Ajkwa-2C); C. Association of *R. apiculata*, *B. gymnorhiza* and *X. granatum* (Minajerwi-1C and Tipuka-2C); D. Association of *R. apiculata* and *B. parviflora* (Kamora-1A, Tipuka-1B, Tipuka-1C, Tipuka-1A, Kamora-2A, and Kamora-2B); E. Association of *B. gymnorhiza* and *R. apiculata* (Minajerwi-2C and Tipuka-2A); F. Association of *B. gymnorhiza*, *R. apiculata*, *B. parviflora*, and *C. schultzei* (Minajerwi-2B and Tipuka-2B); G. Association of *R. apiculata*, *B. gymnorhiza* and *C. schultzei* (Ajkwa-1A and Ajkwa-1B); H. Association of *R. apiculata* and *B. gymnorhiza* (Kamora-2C, Minajerwi-1B, Kamora-1C, Minajerwi-2A, Ajkwa-1C, Kamora-1B, and Minajerwi-1A).

The Bray-Curtis similarity analysis for the crustaceans at all sampling locations can be seen in Figure 3. Meanwhile, Figure 4 shows the analysis based on plot.

Based on the Bray-Curtis similarity analysis for crustaceans from all sampling locations, Ajkwa-2, Minajerwi-2 and Kamora-2 were in one group. This shows that crustacean abundance and species composition are influenced by proximity to the coastline since these three locations are close to the coastline and thus experience more frequent inundation. The most similar locations were Tipuka-1 and Tipuka-2 (67.56%). Other locations that had a similarity of more than 60% were Tipuka-2 and Ajkwa-1 (63.47%) and Tipuka-1 and Ajkwa-1 (61.96%). The most distinct locations were Ajkwa-2 and Minajerwi-1 (21.22%).

Based on plot, the most distinct locations were Minajerwi-1B and Minajerwi-2C. Other sampling plots can be grouped into three clusters with a similarity of 40%. Only two species of crabs were found in Minajerwi-1B, namely *Episesarma lafondi* and *Neosarmatium papuense*, whereas only *Parasesarma leptosome*, *Sarmatium germaini* and *Sesarmoides borneensis* were found in Minajerwi-2C.

The Bray-Curtis similarity analysis for the mollusks from all sampling locations can be seen in Figure 5, while Figure 6 shows the analysis based on plot.

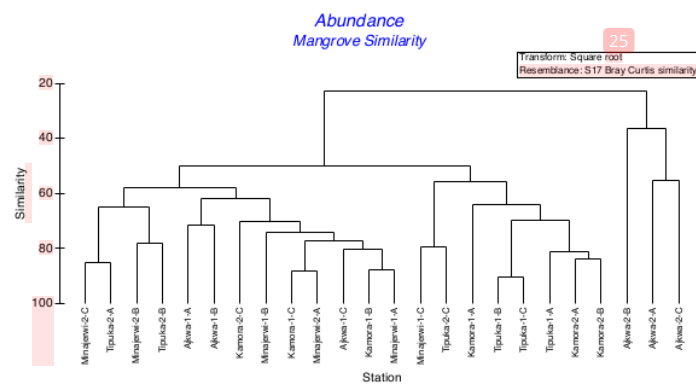
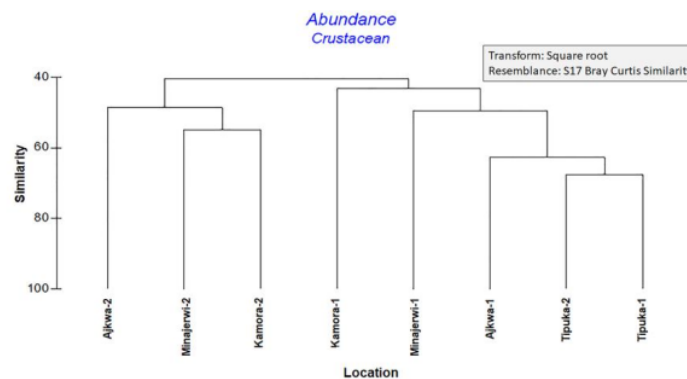
Table 3. Crustacean and Mollusk collected from the sampling location in Mimika District, Papua, Indonesia

	Kamora-1			Kamora-2			Tipuka-1			Tipuka-2			Alkwa-1			Alkwa-2			Minajerwi-1			Minajerwi-2			Total
	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	
Crustacean																									
<i>Alpheus euphrosyne</i>	39	9	4				1	11	1				3	1			3					1			73
<i>Alpheus</i> sp. B	1																1								6
<i>Caridina</i> sp.	1						3										1								5
<i>Clibanarius longitarsus</i>																									11
<i>Clitoceloma ananaparens</i>	8	15	23	1	1	13	7	1	1	4	1	18	6	5	12	2	14	8	2	5	68				215
<i>Corophium</i> sp.																4									4
<i>Episesarma lafondi</i>																									2
<i>Epixanthus dentatus</i>									1																2
<i>Haberma kamora</i>			2				5		5																17
<i>Helice</i> sp.							2		1										3	2					3
<i>Heteropanope longipede</i>																									6
<i>Ilyograpsus paludicola</i>																									1
<i>Ilyoplax dentatus</i>																									1
<i>Labunium politum</i>																									1
<i>Macrobrachium</i> sp.																									3
<i>Macrophthalmus pacificus</i>																									3
<i>Metapenaeus ensis</i>																									2
<i>Mictyris</i> sp.																									53
<i>Nanosesarma edamensis</i>																									4
<i>Neosarmatium bidentatum</i>																									5
<i>Neosarmatium papuense</i>																									8
<i>Neosarmatium rotundifrons</i>																									5
<i>Paracleistostoma quadratum</i>																									4
<i>Parasesarma charis</i>																									4
<i>Parasesarma cricatum</i>	47	40	134				32	15	1	8							63	179	6			1			280
<i>Parasesarma indianum</i>	31	24	17	8	15	27	2	24	32	8	17	48	22	10	9	145	3		3	44	54				785
<i>Parasesarma gracilipes</i>																									1
<i>Parasesarma rutilimanum</i>	1	8	1	1	3	2	1	18				1		14		26	3	3	1	1	12				38
<i>Parasesarma</i> sp.3																									73
<i>Sarmatium germaini</i>	7	1		25	13	18	1	1	1	2						23	44	30	41	22	2				6
<i>Scylla olivacea</i>			1																						232
<i>Selatium brocki</i>																									1
<i>Sesarnoides borneensis</i>	5	12					6	1	2							1									1
<i>Thalassinia anomala</i>			1																						8
<i>Thalassinia squamifera</i>																									3
<i>Uca coarctata</i>	1	6		9	3				1	1							5								26
<i>Uca perplexa</i>																									64
<i>Uca</i> sp.	2																								3
<i>Uca triangularis</i>				9	3																				16
<i>Utica borneensis</i>	1	1	2																						4
<i>Varuna yui</i>																									1
Total species	14	12	14	6	3	8	7	7	11	7	2	5	3	2	6	14	16	9	7	2	6	9	9	3	41

Table 4. Mean numbers of crustacean and mollusks found in the transect of 25 m2 in Mimika District, Papua, Indonesia

Location	S	N	d	H'	J'	D
Crustacean						
Kamora-1	24	472	2.46 ± 0.07	1.68 ± 0.13	0.65 ± 0.07	0.28 ± 0.09
Kamora-2	8	154	1.16 ± 0.02	1.28 ± 0.12	0.77 ± 0.02	0.34 ± 0.12
Tipuka-1	12	174	1.80 ± 0.07	1.39 ± 0.26	0.66 ± 0.07	0.35 ± 0.07
Tipuka-2	10	117	1.03 ± 0.27	0.92 ± 0.72	0.57 ± 0.27	0.55 ± 0.34
Ajkwa-1	7	79	0.80 ± 0.04	0.95 ± 0.48	0.79 ± 0.04	0.48 ± 0.19
Ajkwa-2	24	729	2.19 ± 0.12	1.46 ± 0.46	0.57 ± 0.12	0.38 ± 0.18
Minajerwi-1	10	45	1.54 ± 0.04	1.40 ± 0.66	0.94 ± 0.04	0.30 ± 0.22
Minajerwi-2	12	318	1.35 ± 0.16	1.34 ± 0.27	0.77 ± 0.16	0.31 ± 0.06
Mollusks						
Kamora-1	9	32	1.39 ± 0.66	1.21 ± 0.62	0.86 ± 0.12	0.31 ± 0.26
Kamora-2	5	23	0.80 ± 0.15	0.42 ± 0.22	0.57 ± 0.15	0.67 ± 0.22
Tipuka-1	0	0	0	0	0	0
Tipuka-2	5	30	1.09 ± 0.27	0.62 ± 0.55	0.77 ± 0.27	0.48 ± 0.17
Ajkwa-1	7	54	0.64 ± 0.67	0.60 ± 0.61	0.64 ± 0.12	0.65 ± 0.26
Ajkwa-2	13	346	1.26 ± 0.37	0.88 ± 0.57	0.53 ± 0.37	0.58 ± 0.30
Minajerwi-1	15	197	1.93 ± 0.13	1.62 ± 0.42	0.73 ± 0.13	0.29 ± 0.13
Minajerwi-2	19	2	0.42	0.16	0.68	0.85

Note: S: Total Species Number; N: Total Number of Individual; d: Species Richness (Margalef); H': Shannon Diversity Index; J': Pielou's Evenness; D: Shannon Dominancy

**Figure 2.** Dendrogram of Bray Curtis similarity of mangrove vegetation among sampling location in Mimika District, Papua, Indonesia. A = 10m, B = 250m, C = 500 m distances perpendicular to the riverbank**Figure 3.** Dendrogram of Bray Curtis similarity of crustacean among sampling location in Mimika District, Papua, Indonesia

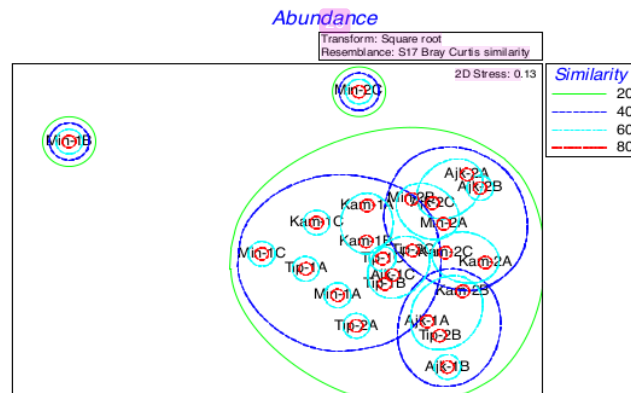


Figure 4. Bray-Curtis similarity of crustacean based on plots in Mimika District, Papua, Indonesia. A = 0m, B = 250m, C = 500 m distances perpendicular to the riverbank

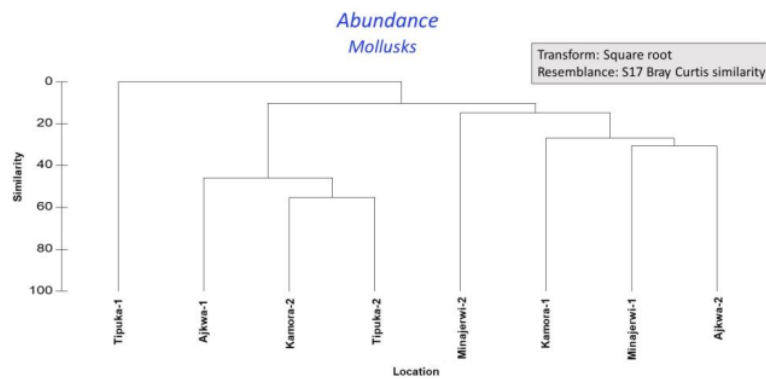


Figure 5. Dendrogram of Bray-Curtis similarity of mollusk among sampling location in Mimika District, Papua, Indonesia

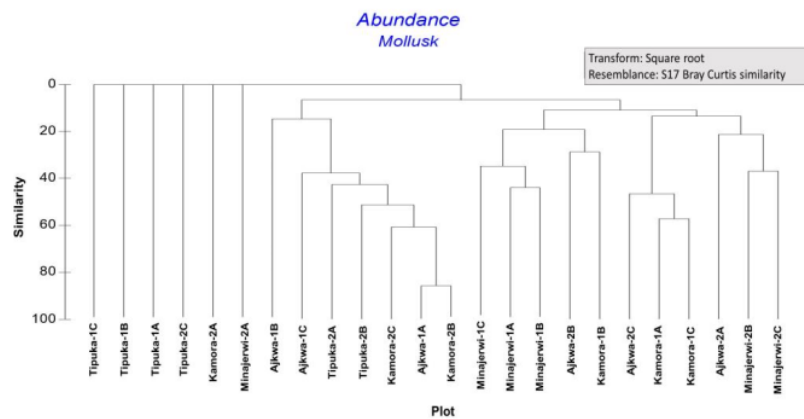


Figure 6. Dendrogram of Bray-Curtis similarity of mollusk based on plots in Mimika District, Papua, Indonesia. A = 0m, B = 250m, C = 500 m distances perpendicular to the riverbank

The highest Bray-Curtis similarity percentage for mollusks was found between Tipuka-2 and Kamora-2 (55.27%). Other locations with high similarity were Tipuka-2 and Ajkwa-1 (48.63%) and Kamora-2 and Ajkwa-1 (42.94%).

Based on plots, the mollusks can be clustered into four clusters. The first cluster comprised Tipuka-1A, Tipuka-1B, Tipuka-1C, Tipuka-2C, Minajerwi-2A and Kamora-2B, where mollusks were absent. Of the other three clusters, the first cluster comprised Ajkwa-1B, Ajkwa-1C, Tipuka-2A, Tipuka-2B, Kamora-2C, Ajkwa-1A and Kamora-2B, the second cluster comprised Minajerwi-1C, Minajerwi-1A, Minajerwi-1B, Ajkwa-2A, and Kamora-1B, and the third cluster comprised Ajkwa-2C, Kamora-1A, Kamora-1C, Ajkwa-2A, Minajerwi-2b, and Minajerwi-2C.

Correlation of mollusks and crustaceans with mangrove association

The results of the PCA used to determine the correlation between the abundance of crustacean and mollusk species with mangrove vegetation association are shown in Figure 7. There is a positive and strong correlation between *P. foresti* and the association of *A. marina* and *S. alba*, between *P. cricatum* and the mangrove association of *R. apiculata* and *B. gymnorrhiza*, and between *C. amamaparensis* and the association of *B. gymnorrhiza*, *R. apiculata*, and *B. parviflora*. *S. germaini* had a quite close relationship with the association of *S. alba* and *A. marina*, *Sesarmoides borneensis* with the association of *R. apiculata* and *B. parviflora*, and *A. euprosyne* with the association of *R. apiculata* and *B. gymnorrhiza*. For mollusks, strong correlations were found for *T. palustris* and *E. aurisjudae* with the association of *R. apiculata* and *B. parviflora*. Correlations were also found

for *N. planospira* and *N. violacea* with the association of *R. apiculata* and *B. parviflora*.

Discussion

A total of 41 crustacean species were found in this study, consisting of 37 crab species, 3 shrimp species, 1 hermit crab species, and 1 mud lobster species. A publication of the crustacean species of Mimika District by Rahayu and Setyadi (2009) revealed 103 species of crustaceans belonging to three infra orders (Anomura, Brachyura, and Thalassinidea) inhabiting the mangrove estuary environment. The number of crab species found in this study is higher compared with other mangrove areas, such as the 31 crab species found in the Sematan mangrove forest, Sarawak, Malaysia (Ashton et al. 2003^a), 13-40 crab species in India (Sakthivel and Fernando 2012; Mohanty et al. 2019), and 25 crab species on the Cameroon Atlantic Coast (Ngo-Massou et al. 2018).

The abundance of crustaceans in this study for 25 m² plots was 87 ± 3.5 individuals. The abundance is higher compared to the study by Ashton et al. (2003^a) in Malaysia, which found abundances of 16 ± 5.9 and 6.3 ± 5.5 crabs, and in Thailand, with the abundance varying from 15 to 52 crabs (Ashton et al. 2003^b). The differences between the results might have been due to the collection method, with Ashton et al. (2003^a and 2003^b) employing a time-based sampling method (15 minutes) in each 100 m² mangrove forest. Meanwhile, this study in Mimika, Papua, was more labor-intensive as it collected crustaceans by excavating sediment with a shovel from 25 m² plots until animals were no longer found. This method seems to be more effective and offers a greater chance of catching crabs hiding in burrows or under fallen trunks. A similar method was applied by Ngo-Masou et al. (2018), with a plot size of 4 m x 4 m.

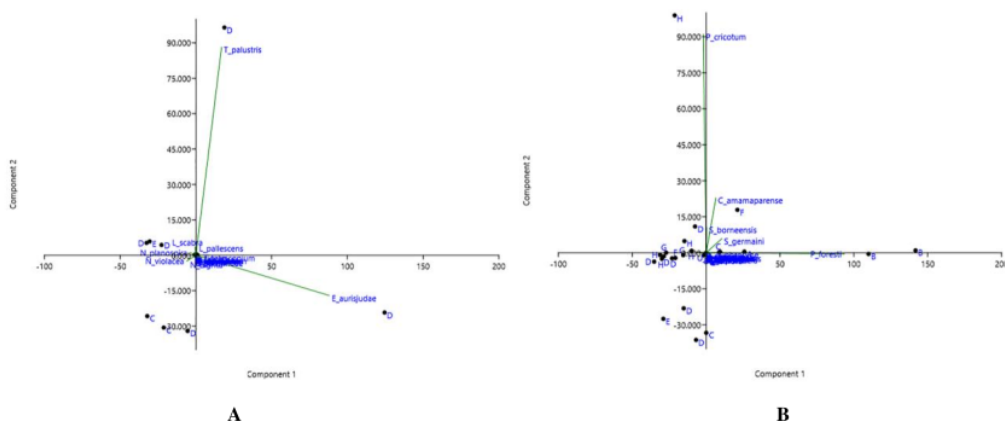


Figure 7. Principal Correlation Analysis of crustacean species (A) and mollusk species (B) with mangrove community types in Mimika District, Papua. A. Association of *S. alba* and *A. marina*, B. Association of *A. marina*, *S. alba*, *B. parviflora* and *R. apiculata*. C. Association of *R. apiculata*, *B. gymnorrhiza* and *X. granatum*. D. Association of *R. apiculata* and *B. parviflora*. E. Association of *B. gymnorrhiza* and *R. apiculata*; F. Association of *B. gymnorrhiza*, *R. apiculata*, *B. parviflora*, and *C. schultzei*. G. Association of *R. apiculata* and *B. gymnorrhiza* and *C. schultzei*. H. Association of *R. apiculata* and *B. gymnorrhiza*.

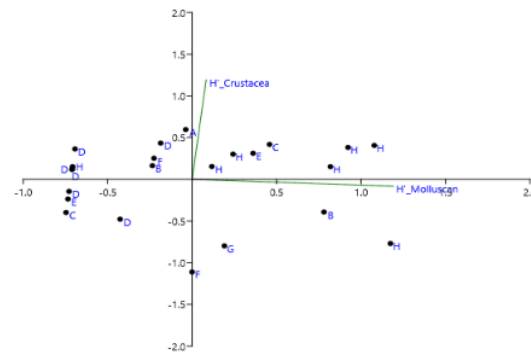


Figure 8. Principal Correlation Analysis of diversity of crustaceans and mollusks with mangrove community types in Mimika District, Papua. A. Association of *S. alba* and *A. marina*, B. Association of *A. marina*, *S. alba*, *B. parviflora* and *R. apiculata*, C. Association of *R. apiculata*, *B. gymnorrhiza* and *X. granatum*, D. Association of *R. apiculata* and *B. parviflora*, E. Association of *B. gymnorrhiza* and *R. apiculata*, F. Association of *B. gymnorrhiza*, *R. apiculata*, *B. parviflora*, and *C. schultzei*, G. Association of *R. apiculata* and *B. gymnorrhiza* and *C. schultzei*, H. Association of *R. apiculata* and *B. gymnorrhiza*

The most abundant and common crustacean species found in this study was *P. indiarum*, with a total of 785 individuals. This crab species had a very wide distribution as it was found in all sampling plots, except the sampling plot in which *Nypa fruticans* appeared. This crab takes shelter under fallen logs and tree trunks or burrows into the muddy bottom of shallow pools. The diet of *Parasesarma* spp. (formerly in the genus *Perisesarma*, Shahdadi and Schubart 2017), which is mangrove leaves, helps to trap energy in the mangrove ecosystem before it is carried away by the tide (Gillikin and Schubart 2004).

Another crab species with a wide distribution was *C. amamaparensis*, with a total of 215 individuals found. This species was only absent in sampling plots with the association of *C. schultzei* and *N. fruticans*. Based on PCA analysis, this species has a strong correlation with the mangrove association of *B. gymnorrhiza*, *R. Apiculata*, and *B. parviflora*. The wide distribution of this species may be related to its dense coat of setae, which have a mud-like color and may serve as camouflage to avoid predators (Lee et al. 2013).

Species of crabs that were abundant but had less distribution were *P. cricatum* (280 individuals from 8 plots), *S. germaini* (232 individuals from 15 plots) and *Sesarmoides borneensis* (107 individuals from 15 plots). Based on PCA, *P. cricatum* has a very strong relationship with the mangrove association of *R. Apiculata* and *B. gymnorrhiza*, whereas *S. germaini* has a fairly close relationship with the association of *S. alba* and *A. marina*. The majority of plots where *S. germaini* were found were located in the seaward margin, with higher salinity and more frequent inundation. Several crustaceans discovered exclusively in the seaward margin of the mangrove at Ajkwa-2, which has a dominance of *S. alba* and *A. marina*, were *Clibanarius longitarsus*, *Ilyoplax dentatus*, *Mictyris* sp., and *Uca perplexa*. It can be assumed that those species prefer to live in conditions of high salinity and with more frequent inundation.

The total number of mollusks found in this study was 32 species, comprising 3 species of bivalves and 29 species of gastropods. Previous publications by Setyadi et al. (Setyadi et al. 2009) recorded 17 species of gastropods and 6 species of bivalve in Mimika District. In Indonesia, at least 48 species of gastropods and 9 species of bivalves have been recorded (Hanum et al. 2014). As a comparison, a study in Aceh Besar and Banda Aceh Besar in Sumatra, Indonesia, recorded 14 species of gastropods and 5 species of bivalves (Dewiyanti and Sofyatuddin 2013), while 44 species of mollusk were recorded in Sematan mangrove forest in Malaysia (Ashton et al. 2003^a), and 14 and 19 species of gastropods and 10 and 3 species of bivalves were recorded, respectively, in Gujarat and Paradeep, India (Thivakaran and Sawale 2016; Yadav et al. 2018). The abundance of mollusks in this study was $1.2 \pm 1.9 \text{ m}^{-2}$, which is much lower than the 371 individuals m^{-2} of gastropods and 28 individuals m^{-2} of bivalves found in Aceh (Dewiyanti and Sofyatuddin 2013), the 64 to 1518 individuals m^{-2} of gastropods and 40 to 833 individuals m^{-2} of bivalves in Gujarat (Thivakaran and Sawale 2016), and the 25 ± 25 and 17 ± 25 individuals m^{-2} of mollusks in Sematan, Malaysia (Ashton et al. 2003^b). The low abundance may be due to the activity of local fishermen as clams and gastropods are the main source of protein for indigenous people living in the coastal areas of Mimika.

Strong correlations of *T. palustris* and *E. aurisjudae* were found with the association of *R. apiculata* and *B. parviflora* (Figure 2). Those two species might have a dependence on the detritus from the litterfall of *B. parviflora* since *R. apiculata* was found in all locations. This conclusion is consistent with the study by Fratini et al. (2001), which found that large numbers of *T. palustris* consume all mangrove species and feed either in clusters or individually on fallen mangrove leaf litter.

Figure 8 shows the correlations of the Shannon diversity indices (H') for crustaceans and mollusks with the ecosystem types in the Mimika District. The graph shows

that the mangrove community with the crustacean highest diversity was the association of *S. alba* and *A. marina* – locations with a high tidal zone and more frequent inundation by seawater. The highest Shannon diversity index was at Ajkwa-2B (1.915), which was associated with *S. alba* and *A. marina* (A). This is higher than that found in the studies in Malaysia and Thailand, which had a highest Shannon diversity index of 1.5 (Ashton et al. 2003^b), or in South Sulawesi, with a highest Shannon diversity index of 0.893 (Hamid and Wardiatno 2018). However, the diversity index is lower than was found for the North Andaman Sea (Kumaralingam et al. 2013), which was 3.38, in Cameroon, which was 3.3 (Ngo-Massou 2018), and in Thailand, which was 2.12 (Macintosh et al. 2002). Salinity may be the contributing factor in the high diversity of crustaceans, which is consistent with another study (Ashton et al. 2003^a).

The diversity of mollusks showed a correlation with the association of *R. apiculata* and *B. gymnorhiza*. The highest Shannon diversity index was at Minajerwi 1B (1.941), which featured the association of *R. apiculata* and *B. gymnorhiza* (H). The association of *R. apiculata* and *B. gymnorhiza* was found mostly in the upper estuary. It seems that mollusk diversity depends on the species composition due to the different food habits of different aquatic faunas. Gastropod species, such as *T. palustris*, are known as major consumers of mangrove leaf litter (Nagelkerken et al. 2008), but microalgae may have contributed towards the gastropod diet (Raw et al. 2017). Meanwhile, bivalves are filter feeders, primarily consuming phytoplankton. Therefore, the mollusk diversities in the mangrove communities are likely to be influenced by physical conditions, such as inundation, salinity, the community structure of the mangrove vegetation, and mangrove detritus (Kabir et al. 2014).

In conclusion, the diversity of crustaceans and mollusk macrofauna in the Mimika District of Papua, Indonesia, is among the highest in the world. One of the main reasons is the vast and undisturbed mangrove forest in Papua, which covers an area of more than 1.4 million hectares, making it one of the largest mangrove forests in the world. However, limited publications have been found on its mangrove ecology and the interaction between the mangrove forest community and mangrove invertebrates. Since mangrove invertebrates play a significant role in decomposing mangrove litter-fall as a source of organic matter for adjacent coastal waters, a better understanding of mangrove invertebrate ecology, particularly in terms of crustaceans and mollusks, will help promote conservation efforts for this pristine mangrove ecosystem.

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valuable inputs. The authors declare no competing interests.

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PAGE 1

PAGE 2

PAGE 3

PAGE 4

PAGE 5

PAGE 6

PAGE 7

PAGE 8

PAGE 9

PAGE 10

PAGE 11

PAGE 12