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Diversity of fish and macrobenthos at the coastal area of Tanjung Kidurong Power Plant (TKPP), Sarawak, Malaysia

Keswarran Kalimuthu[1], Hadi Hamli[2*], Michael Tingang Engan[1], Julaidi Bin Rasidi[1], Mohammad Rabullah[1], Johan Ismail[2], Abdulla-Al-Asif[2], Geoffery James Gerusu[3,4]

1. Sarawak Energy Berhad Menara Sarawak Energy, No. 1, The Isthmus, 93050 Kuching, Sarawak, Malaysia.
2. Department of Animal Science and Fishery, Faculty of Agricultural and Forestry Sciences, Universiti Putra Malaysia Bintulu Sarawak Campus, Jalan Nyabau 97008, Bintulu, Sarawak, Malaysia
3. Department of Forestry Science, Faculty of Agricultural and Forestry Sciences, Universiti Putra Malaysia Bintulu Sarawak Campus, P.O. Box 396 Jalan Nyabau 97008, Bintulu, Sarawak, Malaysia.
4. Institut Ekosains Borneo, Universiti Putra Malaysia Bintulu Sarawak Campus, P.O. Box 396 Jalan Nyabau 97008, Bintulu, Sarawak, Malaysia.

[*]Corresponding Author: hadihamli@upm.edu.my

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ABSTRACT

The regular assessment of faunal diversity near the energy power plant has gained the interest of many researchers. The activity and the effluent discharged from the power plant have remarkably stressed the adjacent assemblage of the alpha biotic community surrounding the power plant. Hence, this study aimed to assess the alpha faunal diversity of fishes and benthos in the bordering areas of Tanjung Kidurong Combined Cycle Power Plant (TKCCP), Bintulu Sarawak. The investigation was conducted in the coastal area from 2019 to 2020. Different ecological indices such as the evenness index, Margalef richness, and Shannon-Weiner diversity index were implemented, along with the cluster analysis of other stations. A number of 141 fish individuals were recorded, containing 40 species of 19 families. In addition, 13182 individuals of benthos communities from six classes and 37 species were identified. A percentage of 78 comprised fishes, while 22% were identified as crustaceans. Among the benthos addressed, Foraminifera was the major group (74%), followed by bivalve (10%) and Scaphopoda (7%). Compared to SEB2, 3 & 4, SEB1, the nearest to the power plant, recorded the highest richness, number of species, and diversity indexes. Cluster analysis, PCA, and nMDS analysis suggested that SEB2, SEB3, SEB4 had similar biodiversity compositions. The study of benthos indicates that SEB1 possesses a distinguished value of diversity and evenness indexes. This study would provide future researchers with vital documentation to evaluate the impact of thermal discharge from the power plant on alpha biodiversity in Bintulu, Sarawak, Malaysia.

INTRODUCTION

Malaysia is a land of different freshwater and marine fishes, with 1951 species belonging to 704 genera, 186 families and 37 orders. Among them, 710 species are commercially significant for the Malazian economy **(Mazlan *et al*., 2005; Chong *et al*., 2010)**. The fisheries resources are under massive threat due to over-exploitation of living resources, massive reclamation and development, discharge of harmful industrial and domestic wastes, in addition to impact of the energy developmental projects **(Yusoff *et al*., 2006)**. Habitat loss or modification, by-catch, overfishing, endemism, pollution, and sedimentation are major factors threatening the native, coral-associated, seagrass associated, mangrove associated, river estuarine, brackish-water, euryhaline and marine fish species **(Chong *et al*., 2010)**.

Electric power division is a foremost vital component within the broader energy framework to measure a nation's development index for Malaysia and worldwide countries **(Munasinghe, 1990)**. In 2016, Malaysia produced 148.3 billion kWh of electricity, whereas the annual consumption was 136.9 billion kWh **(Central Intelligence Agency, 2021)** which contributes with 5.7% GDP (Energy Commission **(Suruhanjaya Tenaga), 2017)**. Compared to gross Malaysian production, Sarawak alone produces 4643 MW, which comprised 3444 MW of Hydroelectricity from different dams around the state. The gas-fired thermal power plant produces 619 MW, and the coal-fired thermal power plant produces 580 MW **(Global Energy Observatory, 2020; Sarawak Energy Berhad, 2020)**. As an industrial city, high energy consumption is required to fulfil the necessity of basic electricity. Therefore, a major thermal power plant named Tanjung Kidurong Combined Cycle Power Plant, with a maximum production capacity of 515 MW has been established to produce electricity since 2020.

Despite the benefits of providing essential energy, coastal power plants can affect marine ecosystems differently, and two negative impacts have been recognized as acute. Firstly, drawing enormous quantities of seawater used for cooling in condenser systems; they subject planktonic organisms to a sensitive interaction of thermal, mechanical, and chemical stresses. Secondly, power plants raise the temperature of estuaries, bays, and the open sea around the site of discharge of their heated effluents, which can threaten the adjacent biodiversity, especially fishes and benthos fauna **(Briand, 1975)**. At the same time, the effects of thermal discharges upon marine fauna have received considerable attention in the past decade, and are the subject of several current reviews around the globe **(Chen *et al*., 2015, 2018; Sonawane, 2015; Jebakumar *et al*., 2018; Rathoure, 2018; Santiago & Lagman, 2018)**.

Altough Malazia has 56 hydro, gas-fired, coal-fired, oil-fired, and hybrid power plants around the city, very few biodiversity assessments were conducted in this area, creating a huge research gap in the power generation biodiversity research **(Ali, 1996; Chew *et al*., 2015)**. Only a few studies were conducted in the Eastern part of Malaysia, but no other research focused on the determination of the overall biodiversity adjacent to the thermal power plant in this region, and Sarawak in particular **(Nyanti *et al*., 2012; Nyanti *et al*., 2014; Hoque *et al*., 2015; Manjaji-Matsumoto *et al*., 2016)**. Thus, this study was organized to investigate the diversity of fish and benthos fauna in the adjacent coastal areas of Tanjung Kidurong Combined Cycle Power Plant (TKCCPP) to fill the information gap and assessment of biodiversity.

MATERIALS AND METHODS

1. Study site

Four stations were subjected to study in the coastal area of Bintulu near the Tanjung Kidurong Combined Cycle Power Plant (TKCCPP) (Table 1& Fig. 1). The location of the station was selected based on its distance from the source of the thermal plume.

Table 1. Sampling sites and coordinates of the present study

Name of the sampling station	Code	Coordinates
Sarawak Energy Berhad-1	SEB1	3˚18’05.8” N 113˚05’20.7” E
Sarawak Energy Berhad-2	SEB2	3˚18’48.4”N 113˚04’55.5”E
Sarawak Energy Berhad-3	SEB3	3˚20’35.9”N 113˚08’1.9”E
Sarawak Energy Berhad-4	SEB4	3˚20’59.7”N 113˚07’52.0”E

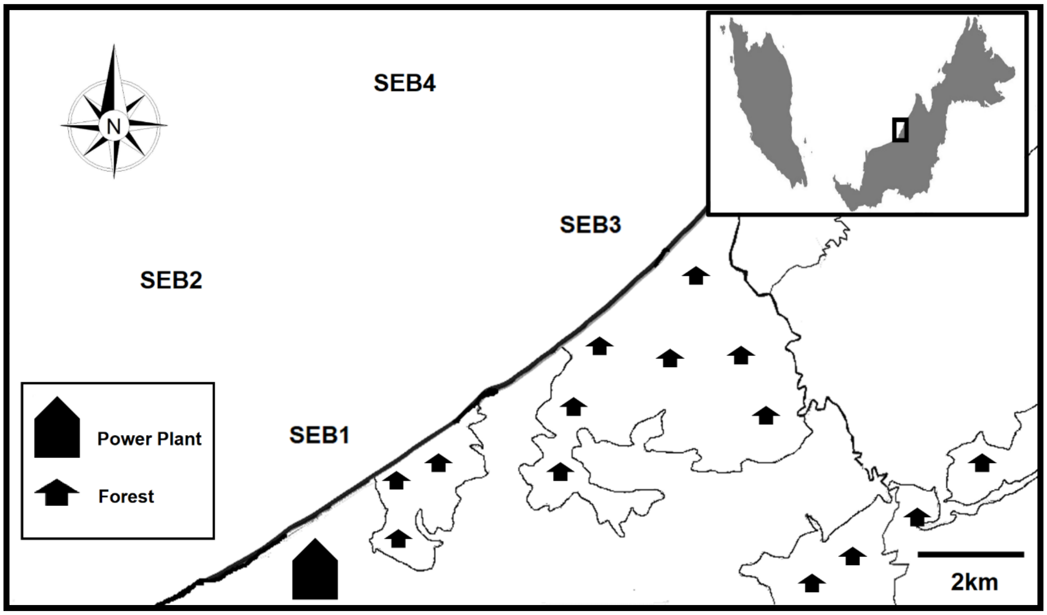

Fig. 1. Map showing sampling locations near Tanjung Kidurong Combined Cycle Power Plant (TKCCPP)

2. Sampling procedure

2.1. Fish sampling

A total of 4 sampling stations (Sarawak Energy Berhad), namely SEB1, SEB2, SEB3, and SEB4 were considered for fish sampling. Sampling was carried out twice between October 2019 and January 2020. Fish samples were collected using fishing gear (gill net), with 100 m length and 2 m wide; it had three layers of net with mesh size of 1, 2 and 3 inches. The nets were drifted for each sampling site for an hour. The collected fish samples were preserved in an icebox and transported to the laboratory for identification and further analysis. Fish samples were identified based on data previously recorded and published works from Malay Peninsular and East Malaysia **(Mazlan *et al*., 2005; Matsunuma *et al*., 2011; Kimura *et al*., 2015; Du *et al*., 2019)**. The taxonomical details, habitats, availability and the IUCN global status were assessed and presented following the work of **Hossain *et al.* (2016)**.

2.2. Benthos sampling

The Benthic sample was collected using Ekman grab from all four stations at the discharge sites (SEB1, SEB2) and two stations point in the control areas (SEB3, SEB4). Three replicates of the sample were collected from each station, and placed in a plastic bag. The sampled benthos with sediments were preserved in an icebox and transported to the laboratory for identification and further analysis. The sediments were sieved using 0.5–1 mm size and preserved using 10% formalin. Preserved samples were examined under a microscope (Leica CME compound microscope, 160 mm tube length), counted, and identified at the laboratory, based on the methods of **Fauchald (1977)**, **Poutiers (1998)**, **Al-Hakim and Glasby (2004)** and **Al-Asif *et al*. (2020)**.

3. Data analysis

The total number of individuals from every species was recorded according to the sampling station. Ten, data were analyzed for diversity, evenness, and richness indices based on the following formula:

Shannon-Weiner Diversity Index (*H*) **(Shannon &Weaver, 1964)**,

$$H = \frac{nlog10\,n - \sum fi\,log10\,fi}{n}$$

Where, n = total number of individuals

fi = number of individuals in species I, i=1,2,3…, n

Margalef richness index (*D*) **(Margalef, 1968)**

$$D = \frac{S-1}{log10\,n}$$

Where, *S* = total number of species

n = total number of individuals

Shannon equitability (E_H), **(Shannon, 1948)**

$$E_H = \frac{H}{lnS}$$

Where, *H* = diversity of species

S = total number of species

The cluster analysis was conducted following Bray-Curtis similarity, and the diversity indices, such as Shannon-Weiner diversity index (H), Margalef richness index (D), and Shannon equitability (EH) that were measured using PAST, 4.03 software **(Hammer *et al*., 2001)**. The PCA of total biodiversity, cluster dendrogram based on Pearson correlation coefficient matrix-unweighted pair-group average method, and the multidimensional scaling (MDS) analysis were performed using **XLSTAT (2021)** (version 2019.2.2).

RESULTS

1. Fish species

A total of 29 (78%) species from 15 families of fishes, and 11 (22%) species of crustaceans from 4 families have been found in all stations (SEB1, 2, 3 and 4) (Fig. 2).

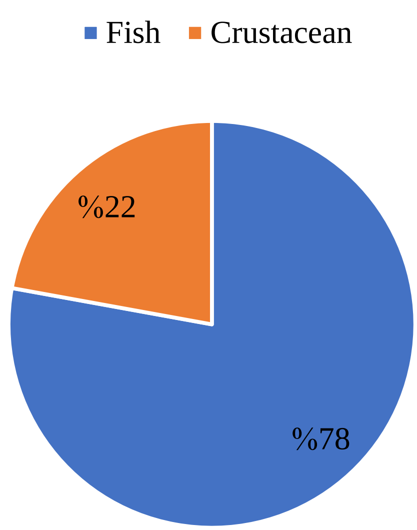

Fig. 2. Percentage of fish and crustaceans from sampling locations

It was noticed that, the dominant species at the sampling site was that of *Opisthopterus tardoore* from Pristigasteridae family, recording 21.3% of the total individuals registered. The SEB4 comprised the highest individual numbers compared to SEB1, SEB2 and SEB3. Penaeidae was the most dominant family with eight species recorded during the study period, compared to other families. SEB1 showed the highest number of fish species (21) followed by SEB4, SEB3 and SEB2, respectively (Table 2).

Table 2. Fish and crustacean compositions of four sampling locations

Order	Family	Scientific name	Habitat	Common name	Local name	Availability	IUCN status	Stations			
								SEB 1	SEB 2	SEB 3	SEB 4
Fishes											
Aulopiformes	Synodontidae	*Harpadon nehereus*	MAR;BW	Bombay-duck	Lumi	TYS	NT	√			√
Carangaria	Polynemidae	*Polydactylus sextarius*	MAR;BW	Black spot threadfin	Senangin	R	NE	√			
Carangiformes	Carangidae	*Selaroides leptolepis*	MAR;BW	Yellow stripe scad	Selar kuning	R	LC	√			
Carcharhiniformes	Carcharhinidae	*Carcharhinus borneensis*	MAR	Borneo shark	Yu borneo	R	CR				√
		Carcharhinus melanopterus	MAR;BW	Blacktip reef shark	Yu sirip hitam	R	VU				√
Clupeiformes	Pristigasteridae	*Opisthopterus tardoore*	MAR;BW	Tardoore	Puput	TYL	LC	√	√	√	√
	Clupeidae	*Sardinella fimbriata*	MAR;BW	Fringe scale sardinella	Tamban	TYS	LC				√
	Dussumieriidae	*Dussumieria acuta*	MAR; BW; FW	Rainbow sardine	Tamban bulat	TYS	LC				√
	Engraulidae	*Coilia borneensis*	BW; FW	Bornean grenadier anchovy	Gonjeng	TYS	DD			√	
		Coilia rebentischii	MAR;BW	Many-fingered grenadier anchovy	Gonjeng	TYS	DD			√	√
		Setipinna taty	MAR;BW	Scaly hairfin anchovy	Empirang	TYS	LC			√	
		Setipinna tenuifilis	MAR; BW; FW	Common hairfin anchovy	Empirang	TYL	DD	√			√
		Stolephorus commersonii	MAR;BW	Commerson's anchovy	Bilis	TYL	LC	√		√	√
		Thryssa hamiltonii	MAR; BW; FW	Hamilton's thryssa	Empirang	TYL	LC		√	√	√
Eupercaria	Gerreidae	*Pentaprion longimanus*	MAR;BW	Longfin mojarra	Senohong	TYL	LC	√		√	√
		Pentaprion sp.	MAR;BW	-	Senohong	-	-			√	√
	Sciaenidae	*Dendrophysa russelii*	MAR; BW; FW	Goatee croaker	Gelama	TYS	LC	√			
		Johnius belangerii	MAR;BW	Belanger's croaker	Gelama	R	LC	√			
		Johnius dussumieri	MAR;BW	Sin croaker	Gelama	TYL	LC	√	√	√	
		Otolithes ruber	MAR;BW	Tigertooth croaker	Gelama	TYS	LC	√	√		
		Pterotolithus lateoides	MAR;BW	Bigmouth croaker	Gelama	TYS	DD		√		
Myliobatiformes	Dasyatidae	*Brevitrygon imbricata*	MAR; BW; FW	Bengal whipray	Pari pasir	R	VU			√	
Ovalentaria	Ambassidae	*Ambassis gymnocephalus*	MAR; BW; FW	Bald glassy	Seriding Putih	R	LC	√			

Perciformes	Stromateidae	*Pampus argenteus*	MAR	Silver pomfret	Bawal putih	TYS	VU			√	
Scombriformes	Scombridae	*Rastrelliger kanagurta*	MAR	Indian mackerel	Kembong	TYS	DD				√
Siluriformes	Ariidae	*Arius* sp.	MAR;BW	-	Duri	-	-		√	√	
		Netuma thalassina	MAR; BW; FW	Giant catfish	Duri	TYS	LC				√
		Osteogeneiosus militaris	MAR; BW; FW	Soldier catfish	Bedukang	TYL	NE	√	√	√	
Tetraodontiformes	Tetraodontidae	*Arothron meleagris*	MAR	Guineafowl puffer	Buntal	R	LC	√			
Crustacea											
Decapoda	Epialtidae	*Doclea rissoni*	MAR	-	Ketam	R	NE		√		
	Penaeidae	*Metapenaeus brevicornis*	MAR	-	Udang merah	R	NE	√			
		Metapenaeus ensis	BW	Greasyback shrimp	Udang kunyit	R	NE				√
		Alcockpenaeopsis hungerfordii	BW	Dog shrimp	Udang	R	NE	√			
		Batepenaeopsis tenella	MAR	-	Udang	TYS	NE		√	√	
		Penaeus indicus	BW	Indian white prawn	Udang putih	TYS	NE				√
		Penaeus latisulcatus	MAR	-	Udang susu	R	NE	√			√
		Penaeus merguiensis	BW	Banana prawn	Udang putih	TYL	NE	√	√	√	√
		Penaeus semisulcatus	BW	Green tiger prawn	Udang harimau	TYS	NE			√	√
	Portunidae	*Scylla paramamosain*	BW	Green mud crab	Ketam bakau	TYS	NE	√	√		
Stomatopoda	Squillidae	*Harpiosquilla harpax*	BW	Robber harpiosquillid mantis shrimp	Udang lipan	TYS	NE	√			√

*MAR, Marine water; BW, Brakishwater; FW, Freshwater; R, rare; TYS, throughout the year small amount, TYL, throughout the year large amount; NE, Not Evaluated; VU, Vulnurable; LC, Least Concern; DD, Data Deficient; CR, Critically Endangered; NT, Near Threatened

O. tardoore was the dominant fish species recorded at the SEB1, SEB2, and SEB4, with percentages of 20.9, 18.8, and 25, respectively. However at SEB3, *Pentaprion longimanus* was the dominant species with 19.2%. The other species from the four stations constitued less than 14% of the total number from every station.

Shanon-Wiener diversity index showed that SEB1 is the highest diversity relative to other stations (2.68); whereas, with 2.31, SEB2 displayed the lowest diversity index value. Resulte of Margalef richness index revealed that, SEB1 has the highest richness (5.05) compared to other stations, followed by SEB4 (4.72), SEB3 (4.60) and SEB2 (3.61). The SEB2 displayed the highest evenness value of 0.91, while SEB4 showed the lowest evenness value of 0.66 (Fig. 3).

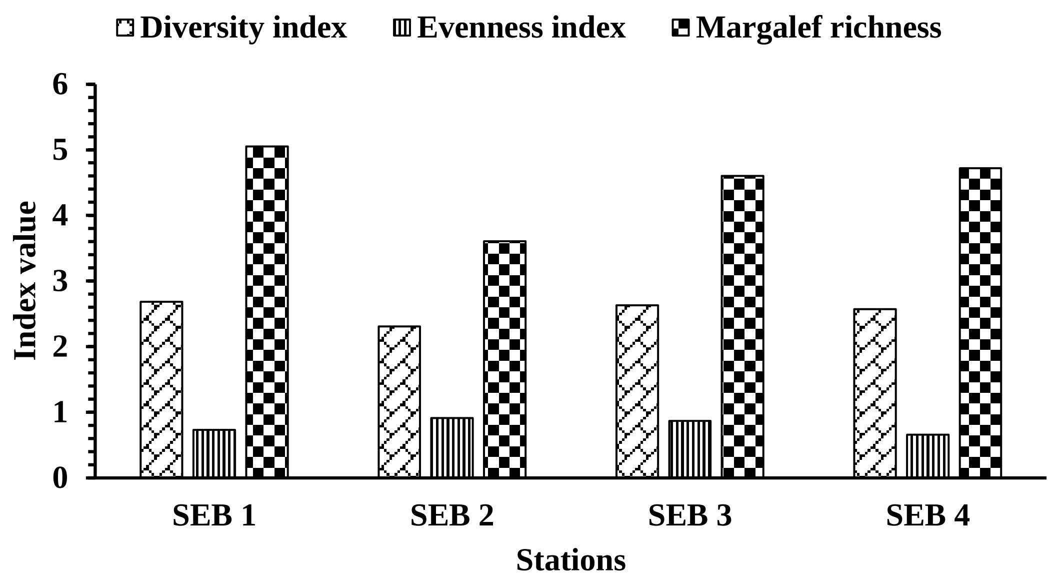

Fig. 3. Histogram showing indices analysis of fishes of the four sampling locations

The cluster analysis of fishes in different stations revealed that two clusters were formed; namely, cluster A and B. Cluster A consists of SEB4 and SEB1; while' SEB2 and SEB3 form Cluster B (Fig. 4).

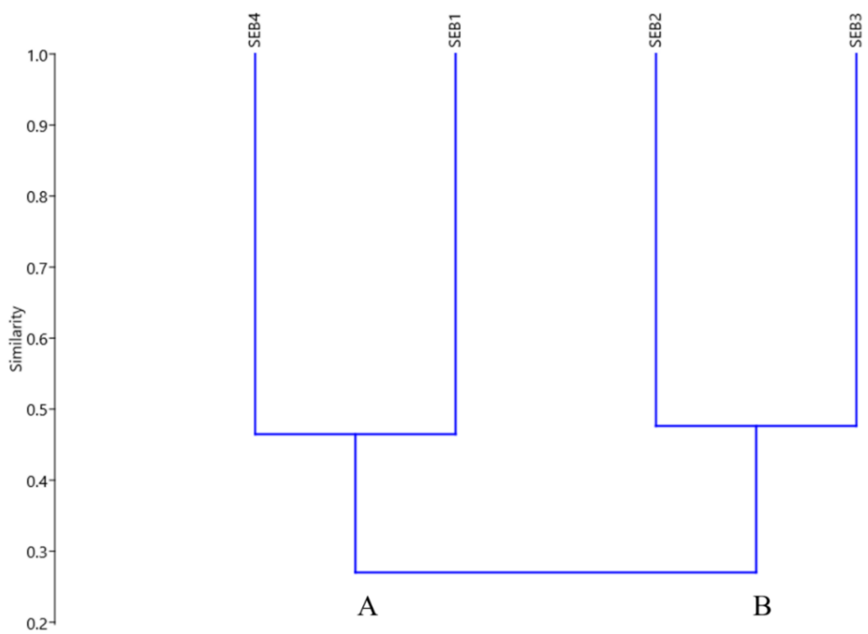

Fig. 4. Histogram showing cluster analysis of fishes from four sampling locations

2. Macrobenthos

A total of 13182 individuals from six classes and 37 species were recorded during the study period (Table 3).

Table 3. Macrobenthic composition related to four sampling locations

Taxa	Family/Species	Stations			
		SEB 1	**SEB 2**	**SEB 3**	**SEB 4**
Polychaeta	*Namalycostis* sp.	5	3	22	21
	Notomastus sp.	4	5	17	22
	Nerillidae	8	30	57	56
	Perinereis sp.	1	0	2	1
	Sternaspis scutata	2	0	4	6
	Eunicidae	4	9	14	14
	Capitellidae	4	14	32	50
	Cirriformia sp.	2	3	5	10
	Spionida sp	2	40	30	29
Annelida	*Nephasoma* sp.	0	4	38	14
Gastropoda	*Conus* sp.	0	2	2	2
	Olividae	1	16	35	10
	Cephalaspidae	0	0	0	1
	Architectonica sp.	1	2	17	30
	Potamididae	0	8	10	4
	Cerithium sp.	6	1	6	5
	Nassariidae	1	1	2	9
	Mangeliidae	0	3	7	2
	Ellobiidae	0	1	5	4
	Neritidae	0	1	1	6
	Throchidae	0	0	2	3
	Naticidae	1	1	8	8
	Haminoeidae	15	14	115	118
	Pyramidellidae	1	11	17	4
	Turritellidae	5	21	13	22
	Epitonium Scalare	0	1	5	0
	Phasianellidae	0	0	2	5
Bivalvia	*Parvicardium* sp.	102	80	130	181
	Patella sp.	7	2	6	6
	Meretrix sp.	40	47	56	74
	Leinucula sp.	11	17	11	22
	Anadara sp.	16	34	62	62
	Nuculana sp.	23	80	153	33
	Osteridae	0	1	0	0
Scaphopoda	*Dentalium* sp.	3	32	46	72
	Creseis sp.	50	105	282	419
Foraminifera	*Elphidium* sp.	285	1450	3890	4120
Total of Individual		**600**	**2039**	**5104**	**5441**
Total of Species		**26**	**32**	**35**	**35**

The Foraminifera showed the highest individual taxa ,with a total of 9745 indv. (73.9%), followed by Bivalvia (1256 indv., 9.5%), Scaphopoda (1009 indv., 7.7%), Gastropoda (589 indv., 4.5%), Polychaeta (528 indv., 4%) and Annelida (56 indv., 0.4%). They were detected at all stations (SEB 1,2,3 and 4) (Fig. 5). Dominant species from the sampling site was that of *Elphidium* sp. from Foraminifera taxa, with 31.3% of the total individual recorded. The SEB4 recorded the highest individual number (5441 indv.), compared to SEB3, SEB2 and SEB1. The highest species quantity was documented at stations SEB3 and SEB4, recording 35 species, respectively.

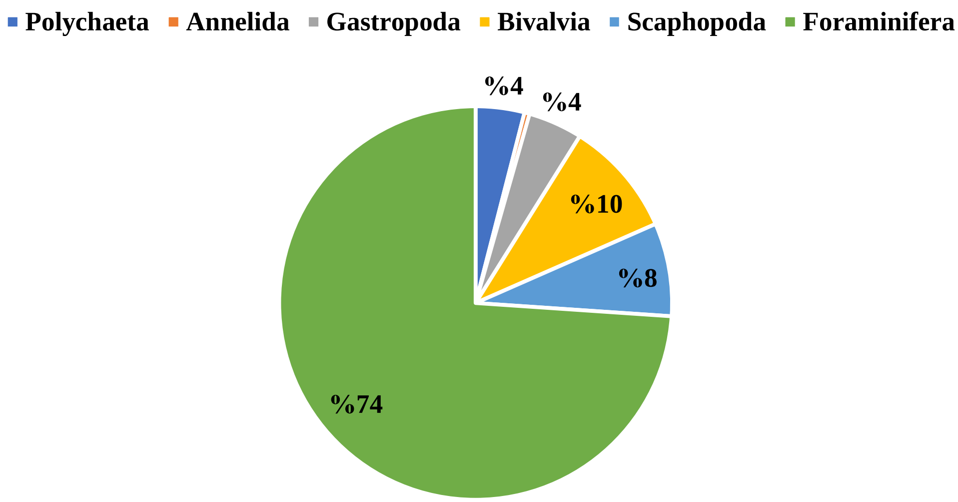

Fig. 5. Percentage of fish and crustaceans in sampling locations

Every station in the study period showed that *Elphidium* sp. was the dominant species recorded with more than 47.5% of the total number of individuals. However, other species from all stations accounted for less than 17% of the total number stated.

The Shanon-Wiener diversity index revealed that SEB1 comprised the highest species diversity (1.91)compared to other stations. Meanwhile, SEB4 demonstrated the lowest diversity index value of 1.18. The evenness index indicated that SEB1 displayed the highest evenness value of 0.2604; whereas, the SEB4 showed the lowest evenness value of 0.0925. Margalef richness index presented that SEB2 contained the highest richness compared to other stations with a recorded value of ,4.07, followed by SEB3 (3.98), SEB4 (3.95) and SEB1 (3.91) (Fig. 6).

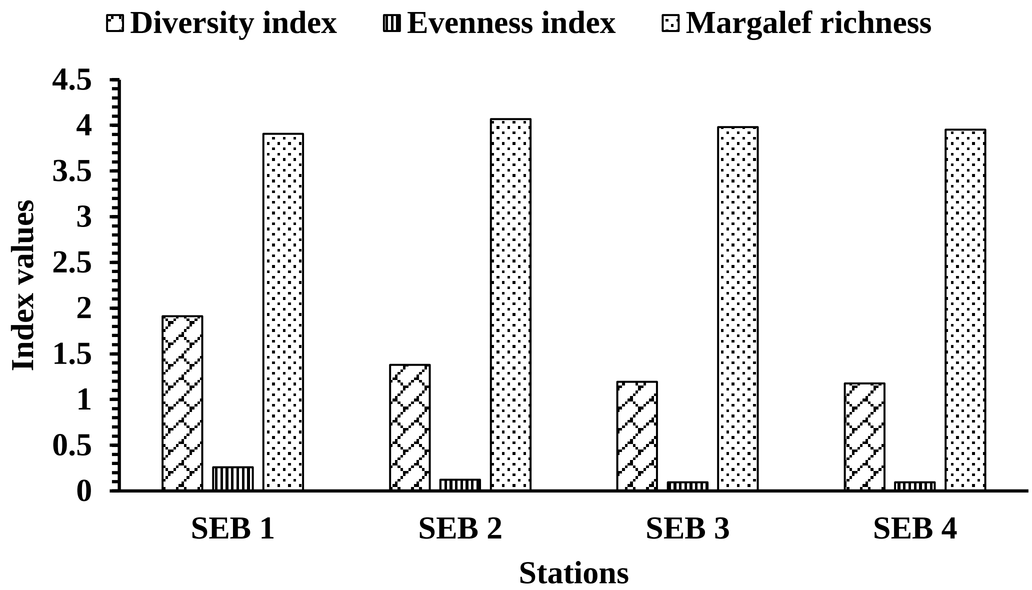

Fig. 6. Histogram showing indices analysis of macrobenthos in four sampling locations

The cluster analysis of macrobenthos revealed that two clusters were formed, such as Cluster I and II. Cluster II was comprised of macrobenthos from SEB1. Moreover, cluster I formed a sub-cluster which represented by Cluster Ia and Ib. Macro-benthos from SEB2 was the foundation for sub-cluster Ia. Furthermore, macrobenthos of SEB3 and SEB4 was the basis for Cluster Ib, (Fig. 7).

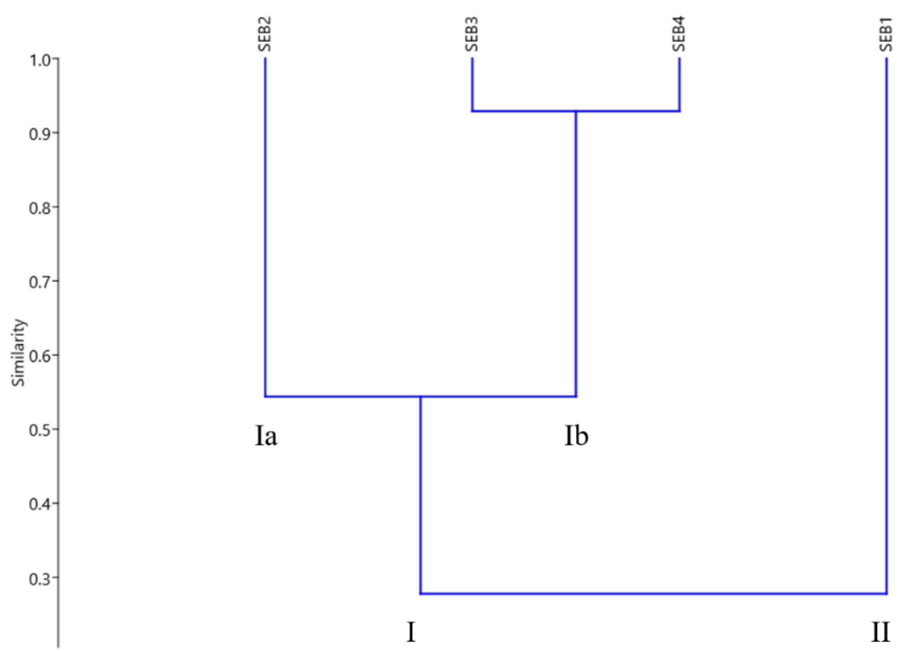

Fig. 7. Cluster analysis of macrobenthos in four sampling locations

3. PCA (Principal component analysis) of the total biodiversity of sampling sites

The PCA of the total biodiversity of sampling sites revealed that the first two PCs contributed 97.90% and 2.03%, cumulatively covered ~99.93% variance with an eigen value of 3.92 (F1) and 0.08 (F2), respectively (Fig. 8).

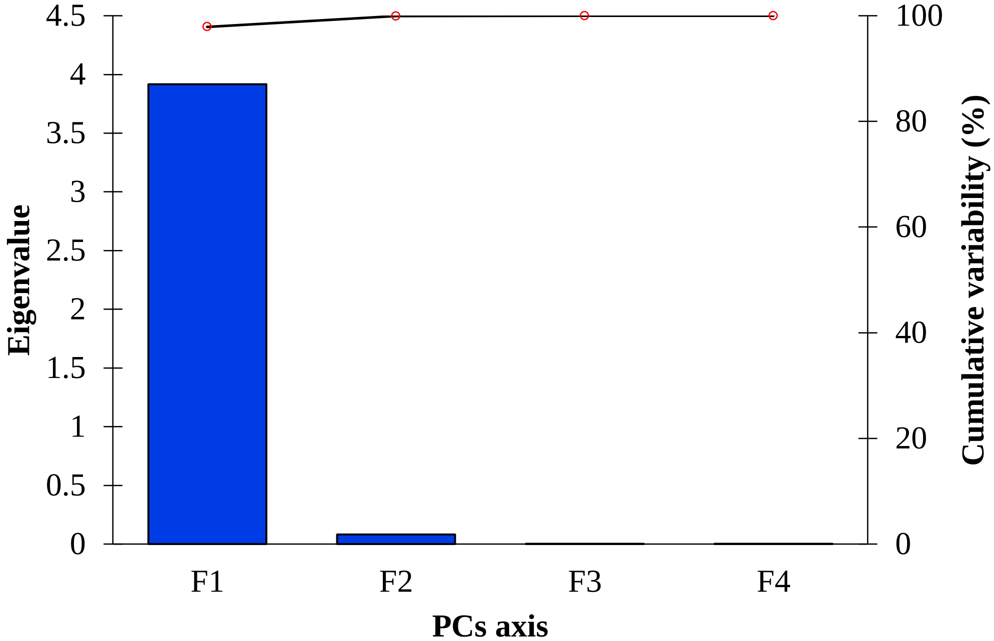

Fig. 8. Histogram showing scree plot of PCA

In the bi-plot and loadings plot, it was observed that the sampling stations SEB1 (0.97), SEB2 (0.99), SEB3 (0.99), and SEB4 (0.99) were highly correlated with the fist PC (F1). In contrast, the similarity of species biodiversity of SEB2, SEB3, and SEB4 was very close (Fig. 9).

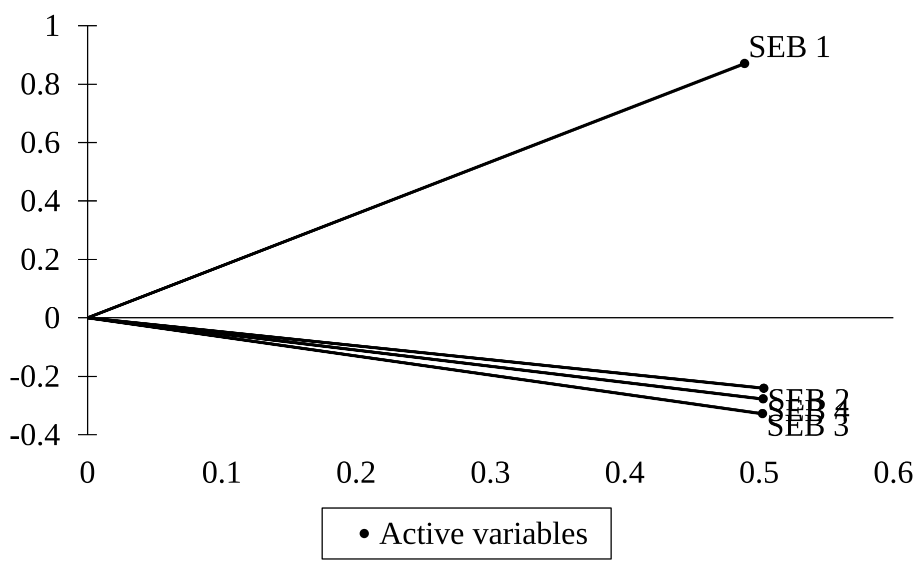

Fig. 9. Histogram showing PCA fish and benthos biodiversity in sampling stations

4. Biodiversity clustering of sampling sites

The cluster dendrogram (Pearson correlation coefficient matrix; unweighted pair-group average method) revealed three distinctive clusters in terms of fish and benthos diversity at the sampling stations. SEB2 and SEB3 formed one cluster with a high similarity level (average distance to centroid= 1225.54); on the other hand, SEB1 and SEB4 are different from other stations (Fig. 10).

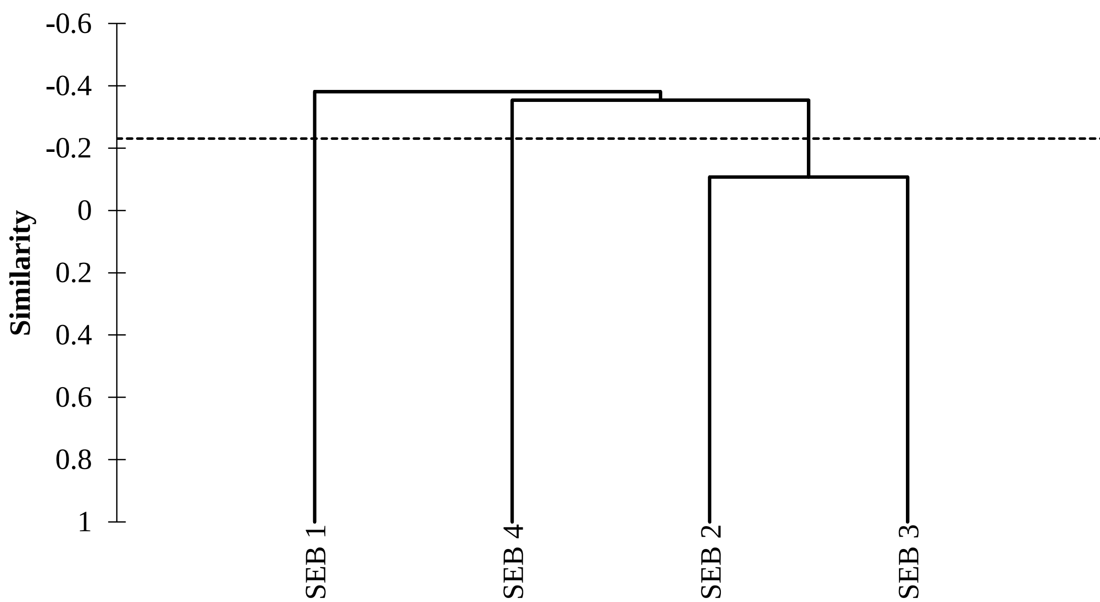

Fig. 10. Cluster dendrogram of fish and benthos diversity in different stations

5. Multidimensional Scaling (MDS) of total biodiversity

With a Kruskal's stress value of 0.04, the multidimensional scaling (MDS) analysis of fish and benthos in different stations indicated that, the MDS dimensions of SEB2 (0.012,-0.001), SEB3 (0.015,-0.002) and SEB4 (0.014,-0.002) were closely correlated with each other; whereas, SEB1 (-0.041, 0.005) maintained a distance with SEB2 (0.053), SEB3 (0.056), SEB4 (0.055). This can be interpreted as a different diversity of fishes and benthos of SEB1 (Fig. 11). The Shepard diagram postulated that the MDS result of fish and benthos diversity was reliable (Fig. 12).

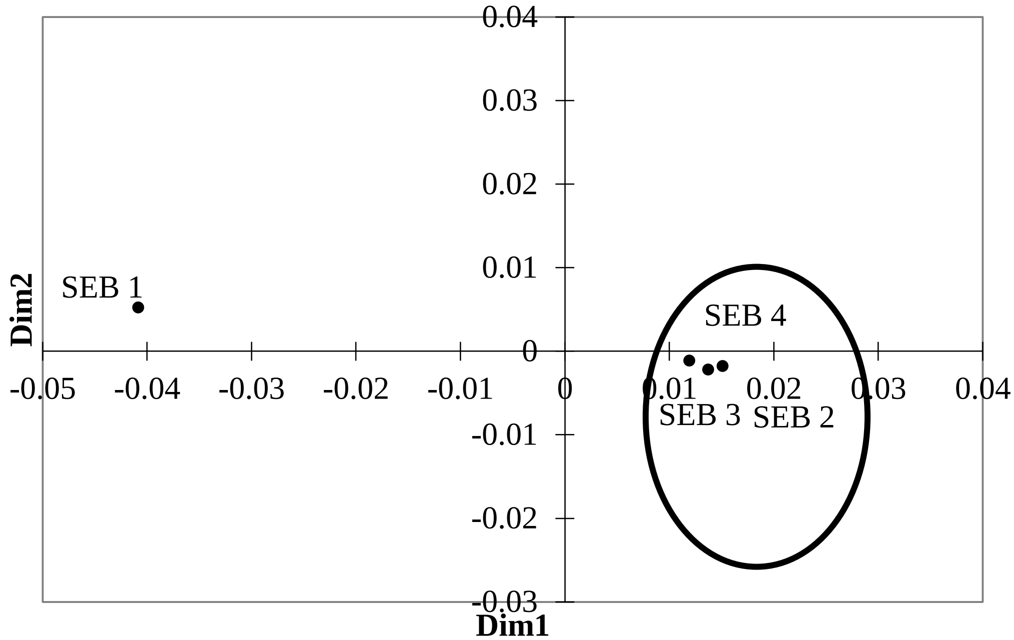

Fig. 11. Multidimensional scaling (MDS) analysis of fish and benthos diversity in different stations

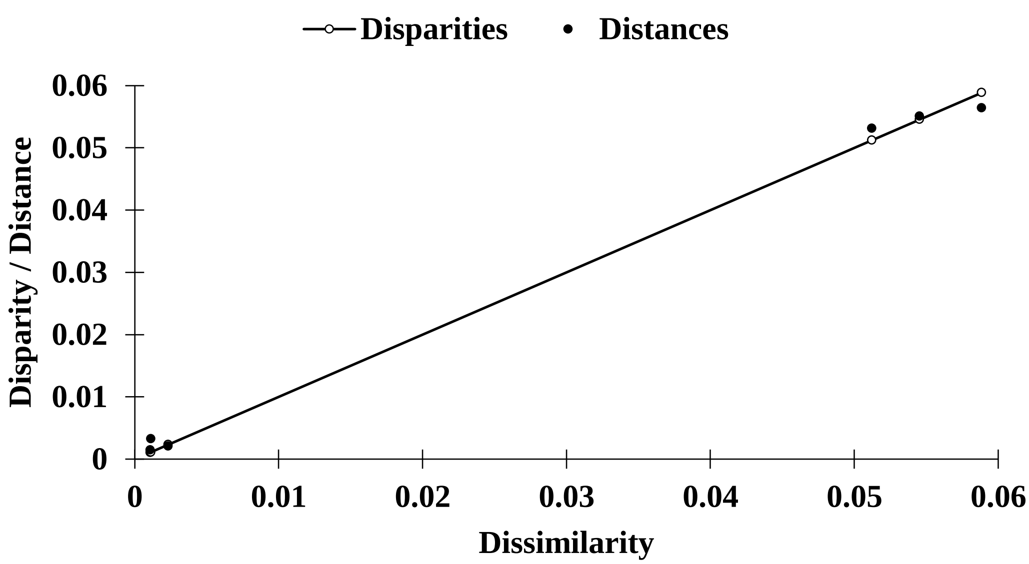

Fig. 12. Shepard diagram of multidimensional scaling (MDS) analysis

DISCUSSION

The assessment of biodiversity and environmental impact is a vital work before and after establishing any infrastructure near the coastal area, especially for the Tanjung Kidurong power plant **(Hill *et al.*, 2009)**. The assessment of existing biodiversity may be beneficial for comparing the overall biodiversity status of a power plant site over time and determining whether or not the infrastructure degrades the environment **(Zari, 2014)**.

On the other hand, environmental and biodiversity assessments assist decision-makers, managers, and policymakers in making decisions and enacting or amending laws in response to the gravity of the situation **(Latawiec *et al*., 2010)**.

The current study assessed the prevailing biodiversity near the Tanjung Kidurong power plant, identifying 40 species of fish and crustaceans. The most dominant and frequently caught fish was *Opisthopterus tardoore*, which has less commercial value, but the ecological niche role of this species was found incredible **(Srihari *et al*., 2018)**. However, the study of **Pradhan *et al*. (2020)** revealed that the fish oil of *Opisthopterus tardoore* has anti-obesity properties, and for better understanding, more study might be conducted on the ecological impact of this species in the Malaysian ecosystem. The current study recorded some of the highly commercial marine fish species from the adjacent area of the Tanjung Kidurong power plant; namely, *Otolithes ruber*, *Dendrophysa russelii* and *Thryssa hamiltonii*, which were recorded in different habitats of Malaysia ad referred to as commercial fish species with high value **(Johan *et al*., 2020; Das *et al*., 2021)**. Families Pristigasteridae, Engraulidae, and Sciaenidae were the most dominant groups in the study sites; whereas the present finding differs from that of **Jalal *et al*. (2012a, b)** and **Rumeaida *et al*. (2014)** who reported the families Ariidae, Pomacentridae, and Nemipteridae as the dominant fish families detected in the tropical estuary of Kuantan, Pahang and Bidong Island. The difference may have occurred due to the estuarine influence on fish species and family since the estuary serves as a foraging ground for a variety of fish **(Leggett, 1984; Potter *et al*., 2015)**.

The current finding suggests that crustaceans were one of the major groups of fauna in the sampling sites; 11 species of crustaceans were recorded from 4 families, including Epialtidae, Penaeidae, Portunidae and Squllidae. The family Epialtidae belongs to the deep-sea king crab species, including *Doclea rissoni* **(Lee *et al*., 2019)**. Fortunately, this crab was found in the coastal shore of Bintulu near the power plant. In the current study, the family Penaeidae contained a number of commercially valuable shrimp species, including *Metapenaeus brevicornis*, *Penaeus indicus* and *Penaeus latisulcatus*; these species were abundant in the study areas and possessed a high market value for both domestic and international consumers **(Rábago-Quiroz *et al*., 2019; Wulandari *et al*., 2019)**. One mantis shrimp, *Harpiosquilla harpax*, was detected during the study, which is common in the South China Sea and Indo-Pacific but uncommon in Malaysian waters **(Rajendra & Yedukondala, 2015; Yan *et al*., 2015; Iftitah *et al*., 2017)**.

The diversity index of fishes for the four sites ranged between 2.31 and 2.68; the richness index ranged between 3.61 and 5.05; on the other hand, evenness index ranged between 0.66 and 0.91. A study of Pulau Langkawi, Malaysia, revealed that evenness index ranged between 0.26 and 0.71, which is less than the present study **(Izzati & Abdullah, 2010)**. **Jalal *et al*. (2018)** found that Sungai Pusu had a diversity index of 1.399, indicating that it was not highly diverse with tropical fish species, and in comparison to the present finding, it showed very low fish diversity. According to

Aryani *et al*. (2020), the diversity index of reservoir fishes in an upstream and downstream setup was 2.10; the richness index was 0.21, and the evenness index was 0.19, all of which are lower than the current finding.

The cluster analysis of fishes revealed two distinct clusters; the closest station to the power plant and SEB4 formed one cluster; whereas, station SEB2 and SEB3 formed another cluster, indicating that the number of fishes in each cluster was nearly identical. Different research groups performed similar cluster analysis, habitats and other groups of the organism **(Al-Asif *et al*., 2020; Johan *et al*., 2020; Ismail *et al*., 2021)**.

In all stations adjacent to the Tanjung Kidurong power plant, the current study identified 37 species or groups of macrobenthos, including Polychaeta, Annelida, Gastropoda, Bivalvia, Scaphopoda, and Foraminifera. Foraminifera covered the majority of the benthos (73.9 %), but the dominant species at the sampling site was *Elphidium* sp. from the Foraminifera taxon. Numerous Foraminifera discovered in Malaysia were dependent on and associated exclusively with environmental factors **(Culver *et al*., 2013; Yahya *et al*., 2014; Minhat *et al*., 2016; Sabri *et al*., 2019)**. In addition, the work of benthic species assemblage by other researchers did not include Foraminifera in their sample, but they reported other groups of benthos (example, Gastropoda, Bivalvia, Polychaeta) **(Hamli *et al*., 2015; Abu Hena *et al.*, 2016; Hamli *et al*., 2016; Hamli *et al*., 2017; Mohamamad & Jalal, 2018; Zakirah *et al*., 2019; Al-Asif *et al*., 2020; Al-Asif *et al*., 2021)**. The benthic individual ranged between 600 and 5441 individuals per station, which coincides with the finding of **Ibrahim *et al.* (2006)**. Variations in fish and benthic composition between habitats could be attributed to the differences in food availability, habitat preference, water quality and predatory presence **(Szarek *et al*., 2006; Sweke *et al*., 2013; Mohamamad & Jalal, 2018; Campanella *et al*., 2019)**.

The diversity index of benthos for the four sites ranged between 1.18 and 1.91; the richness index ranged between 3.91 and 4.07; on the other hand, the evenness index ranged between 0.09 and 0.26. A study from Sungai Pulai estuary, Johor, Malaysia postulated that, the diversity index ranged between 1.15 and 1.64; the richness index ranged between 1.70 and 2.24, and the evenness index ranged between 0.55 and 0.70, which can be considered very close to the present findings **(Shi *et al*., 2014a)**. Another study of macrobenthos from the Semenyih River in Selangor, Peninsular Malaysia, found that the diversity index was 0.98. The richness index was 1.91, and the evenness index was 0.84, with values comparable to the current study **(Yap *et al*., 2003)**. **Ahmad (2018)** studied the benthic community in Sungai Kisap, Langkawi, Kedah, Malaysia and reported a diversity index of 1.28, an evenness index of 0.45, and a richness index of 2.80, all of which are relevant to the current study. However, **Hennink and Zeven (1990)** reported that the Shannon-Weiner Diversity Index was less reliable to assess the variance in the study. Moreover, this index is focused on a sample size that has a high degree of uniformity between species **(Morris *et al*., 2014)**.

According to the cluster analysis of benthic fauna, four stations formed two major clusters, with sub-cluster Ia (SEB2) and Ib (SEB3 and SEB4). Cluster Ib was consistent with high individual and species numbers from both stations, some stations wise cluster analysis were performed in the studies of **Al-Asif *et al*. (2020)** and **Shi *et al*. (2014a, 2014b)**. Hence, macrobenthos were the suitable organism to measure environmental conditions due to benthic organism behaviour. Macrobenthic organisms mostly burier type, which will stay at the same place for a long period **(Verdonschot, 2015; Compton *et al*., 2016)**.

The PCA analysis of the total biodiversity of the study sites revealed that SEB2, SEB3 and SEB4 were highly correlated with each other and the first axis in terms of species abundance and diversity; whereas, the first axis contributes most of the variables (97.90%). According to the PCA results, the first station was distinct from others, regarding species abundance and diversity. The PCA result of **Gholizadeh *et al*. (2012) Al-Asif *et al*. (2020), Mulik *et al*. (2020)** and **Kasihmuddin and Cob (2021)** concurs with that of the present study. The overall (fish and benthos) biodiversity cluster of sampling sites revealed that SEB2 and SEB3 formed one cluster with high similarity. On the other hand, station SEB1 and SEB4 formed separate clusters, which revealed that the first two stations were very similar in biodiversity, SEB1 had lowed diversity of fishes and benthos, and SEB4 recorded higher biodiversity. These sort of clusters were reported in different habitats and organisms in the studies of **Al-Asif *et al*. (2020)** and **Ismail *et al*. (2021)**. Furthermore, non-metric multi-dimensional scaling (MDS) of the total biodiversity supports the result of PCA and cluster analysis, where SEB2, SEB3 and SEB4 were closely correlated, while SEB1 maintained a sharp distance of biodiversity. These sorts of non-metric multi-dimensional scaling were reported in different habitats for fish **(Hajisamae *et al*., 2006; Hussin, 2014; Stephenie *et al*., 2021)** and benthos **(Zaleha *et al*., 2009; Hussin, 2014; Matin *et al*., 2018; Wan Hussin & Lah, 2020)**.

CONCLUSION

The species richness, diversity, and evenness of fish and macrobenthos in the study area reflect the biotic factor conditions along the Tanjung Kidurong Combined Cycle Power Plant's coast. Stations SEB 3 and 4 may have more macrobenthos than fish diversity, while the fish species richness of SEB 1 and 2 was high for being close to the power plant. The present findings reflecting the Similajau National Park, which is near this power plant was not disturbed by the plant. However, continuous assessment with ecological studies are recommended to monitor and sustain the biotic integrity of the national park.

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