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Spatial Mapping: Diversity and Distribution of Demersal Fish in the Southern of South China Sea (Indonesia Fisheries Management Zone 711)

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Abstract

In the future, fisheries management must not be based on biomass measure only, but must use an integrated ecosystem approach. This study was aimed to discover the species diversity level of demersal fish resources in spatial distribution and its relation to the environment. The study was conducted in May and June 2015 by operating a trawl in the assigned stations.

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The spatial distribution was based on the Bray-Curtis index which divided the distribution of demersal fish resources into three clusters. Inshore sites of Kalimantan’s western waters (KLBR) was dominated by Leognathidae, inshore sites of the eastern of Riau Islands waters (KPRI) was dominated by Lutjanidae, and offshore sites of the southern of South China Sea (SSCS) was dominated by Nemipteridae. Offshore sites of the southern of South China Sea (SSCS) had a much better community stability level than that of inshore sites of Kalimantan’s western waters (KLBR) and inshore sites of the eastern of Riau Islands waters (KPRI). This study also demonstrated that environmental factors such as depth, sediment type, salinity, and temperature, affect the distribution and species diversity of demersal fish communities in the southern of South China Sea.

Keywords: diversity; demersal fish; South China Sea.

1. Introduction

When considering the basic structure of a biological system such as a community or an ecosystem, the two fundamental parameters are the number of species and the number of individuals in each of the species [1]. The community structure is usually described by the number of species (richness), the diversity index, the evenness index, and the domination index [2,3,4,5].

According to [6], there is a connection between species distribution and physical factors such as depth, salinity and sediment type, whereas [7] stated that the distribution of demersal fish is related to depth but not related to sediment type, salinity, temperature and turbidity. Generally, fish adapt to changes in the environment by migrating, both horizontally and vertically [8].

In the future, fisheries management must not be based on biomass measure only, but must use an integrated ecosystem approach [1,8,9,10]. Information of the distribution, biomass density and community structure of demersal fish is of utmost importance as input for the success of the management of fishery potential [7,11].

This study was aimed to discover the diversity of demersal fish in spatial distribution, and its relation to the environment. The results of this study are expected to used as consideration in the management of demersal fish resources in the southern of South China Sea (Indonesia Fisheries Management Zone/IFMZ 711).

2. Materials and Methods

2.1. Study Area

This study was conducted in May and June 2015 using Research Vessel (R/V) of Madidihang 02. The study location was the southern of South China Sea with the positions of the trawling stations as depicted in Figure 1.

2.2. Data Collection

Collection of catch data was conducted by using a trawl operated in pre-determined stations, whereas oceanographical data were collected using a CTD that was sunk in the pre-determined stations moments before the trawl was operated.

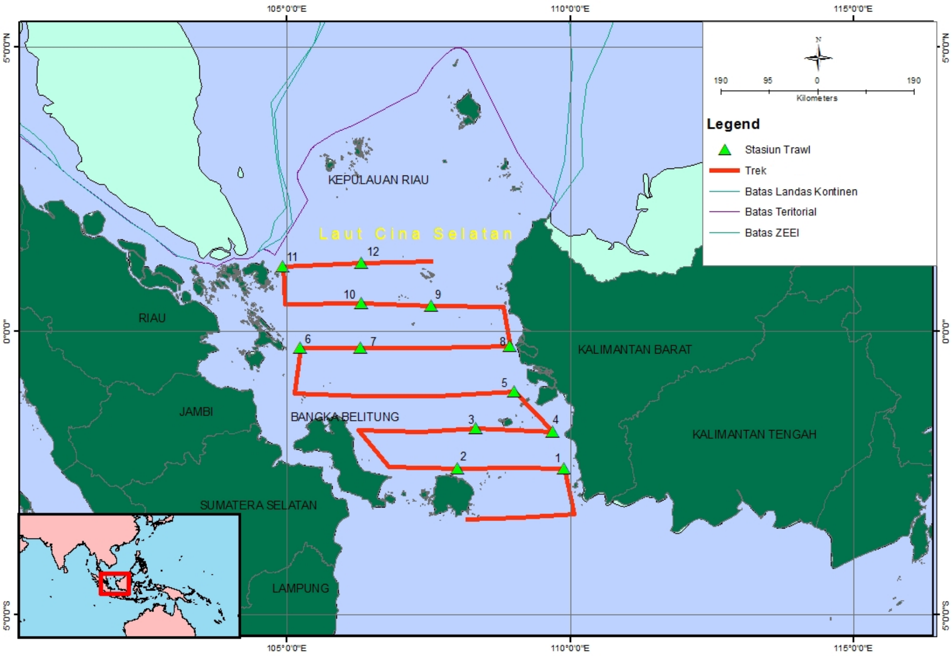

Figure 1: The location map of the research, cruising track, and trawling positions in the southern of South China Sea (Indonesia Fisheries Management Zone 711), the period of May – June 2015.

2.3. Data Analysis

Analysis of the demersal fish diversity used a number of ecological indices, namely the Shannon-Wiener's diversity index[12,13,14,15,16,17], the Pielou's evenness index[3,18], the Simpson's dominance index [19,20], and the Berger-Parker's index.

The Shannon-Wiener's index $H' = -\sum(p_i \ln(p_i))$ ………………………………….. (1)

The Pielou's index $J' = (H' / \ln(S))$ …………………………………………………. (2)

The Simpson's index $D_s = 1 - D = 1 - \sum\{(n_i(n_i - 1)) / (N(N - 1))\}$………………… (3)

The Berger-Parker's index $D_b = N_{max}/N$ ……………………………………………….. (4)

Note: H' = species diversity index, p_i = ratio between the number of individuals in the *i*-th species and the total number of individuals (n_i/N), S = the number of species, N = the number of individuals, n_i = the number of *i*-th individual.

The ecological index value was then related to environmental conditions and analyzed using the principal component analysis (PCA). Therefore, the level of influence of the environmental factors to the existing community structure could be discovered.

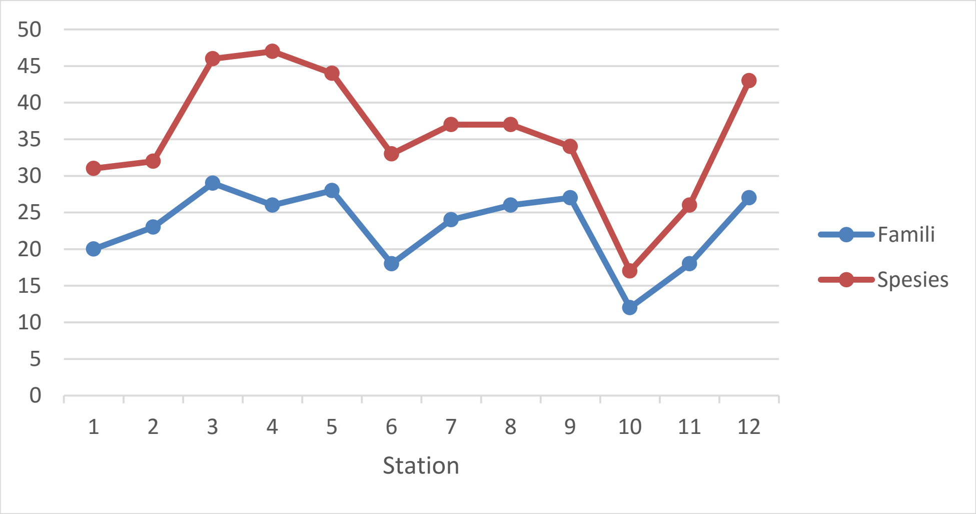

Figure 2: Spatial distribution of demersal fish resources in the southern of South China Sea.

3. Result and Discussion

3.1. Result

1). Spatial distribution

Demersal fishes were evenly distributed throughout the southern of South China Sea (IFMA 711). The largest distribution of species was found in station 4, station 3, station 5, and station 12, repectively. While the largest number of families was found in station 3, station 5, station 9, station 12, and station 4, respectively (Figure 2).

2). Cluster and Multi-Dimensional Scalling (MDS) Analysis

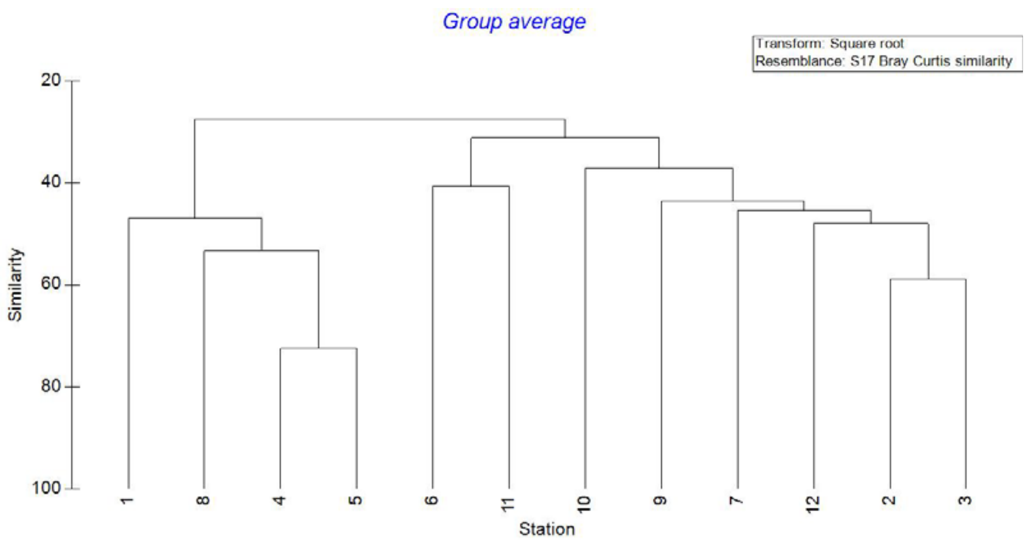

Figure 3: The dendrogram of trawl station classifications based on the similarity index of the demersal fish.

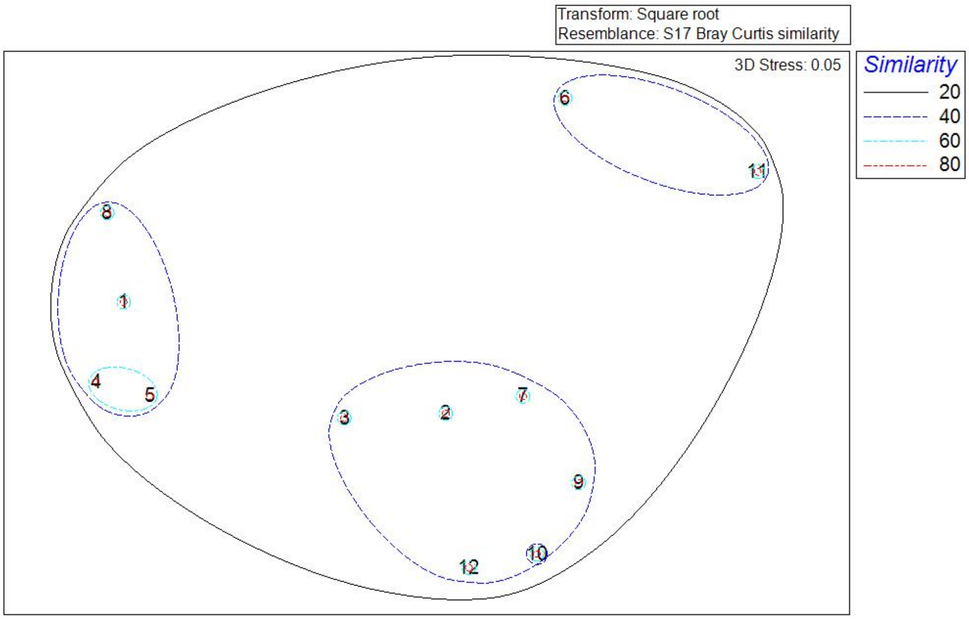

Figure 4: The MDS diagram of trawl station classifications based on the similarity index of the demersal fish.

To simplify the study, the species diversity was classified spatially [21]. The spatial classification of trawl stations was done based on the species similarity index, and the result was 3 (three) trawl station classification clusters (Figure 3 and Figure 4). Cluster 1 consisted of station 1, station 4, station 5, and station 8 which was then referred to as inshore sites of Kalimantan's western waters (KLBR). Cluster 2 consisted of station 2, station 3, station 7, station 9, station 10, and station 12 which was then referred to as offshore sites of the southern of South China Sea (SSCS). Finally, station 6 and station 11 in cluster 3 which were then referred to as inshore sites of the eastern of Riau Islands waters (KPRI).

Figure 5 presents the dominant family in inshore sites of Kalimantan's western waters (KLBR), Leognathidae, with a weight composition of 65.4%, followed by Nemipteridae and Mullidae with weight compositions of 6.3% and 3.9%, respectively. Inshore sites of the eastern of Riau Islands waters (KPRI) was dominated by the Lutjanidae, Tetraodontidae, Haemulidae, and Nemipteridae families with weight compositions of 31.9%; 22.1%; 16.6%; and 4.5%, respectively, whereas offshore sites of the southern of South China Sea (SSCS) was dominated by Nemipteridae, Mullidae, and Serranidae with weight compositions of 17.7%; 13.7%; and 10.0%, respectively.

3). Diversity indices based clustering

In this study, it was discovered that the diversity index (H') ranged between 1.06 - 2.85, the evenness index (J') ranged between 0.28 - 0.79, and the Simpson's dominance index and the Berger-Parker's index ranged between 0.09 - 0.64 and 0.19 - 0.80, respectively, in inshore sites of Kalimantan's western waters (KLBR). Inshore sites of the eastern of Riau Islands waters (KPRI) had a biodiversity index (H') ranging between 1.69 - 2.60, an evenness index (J') ranging between 0.49 - 0.80, and a Simpson's dominance index and Berger-Parker's index ranging between 0.12 - 0.39 and 0.31 - 0.61, respectively. Offshore sites of the southern of South China Sea

(SSCS) had the highest diversity index (H') and evenness index (J'), between 2.19 - 3.10 and 0.65 - 0.88, and the lowest Simpson's dominance index and Berger-Parker index ranging between 0.05 - 0.20 and 0.12 - 0.41 (Figure 6).

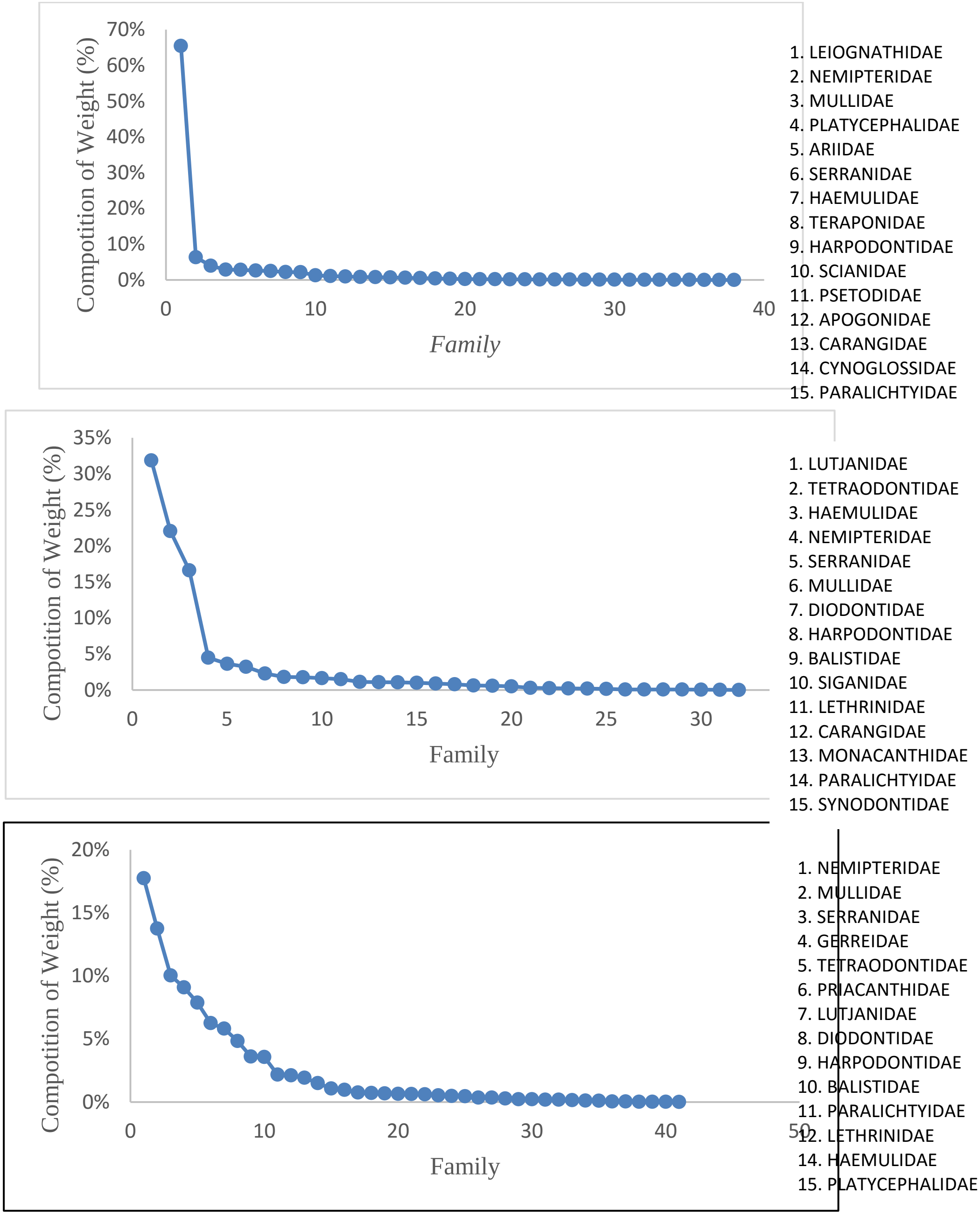

Figure 5: The composition of the dominant families based on spatial distribution : (a) Inshore sites of Kalimantan's western waters (KLBR), (b) Inshore sites of the eastern of Riau Islands waters (KPRI), (c) Offshore sites of the southern of South China Sea (SSCS).

4). The Analysis of the Effect of Environmental Conditions on the Ecological index

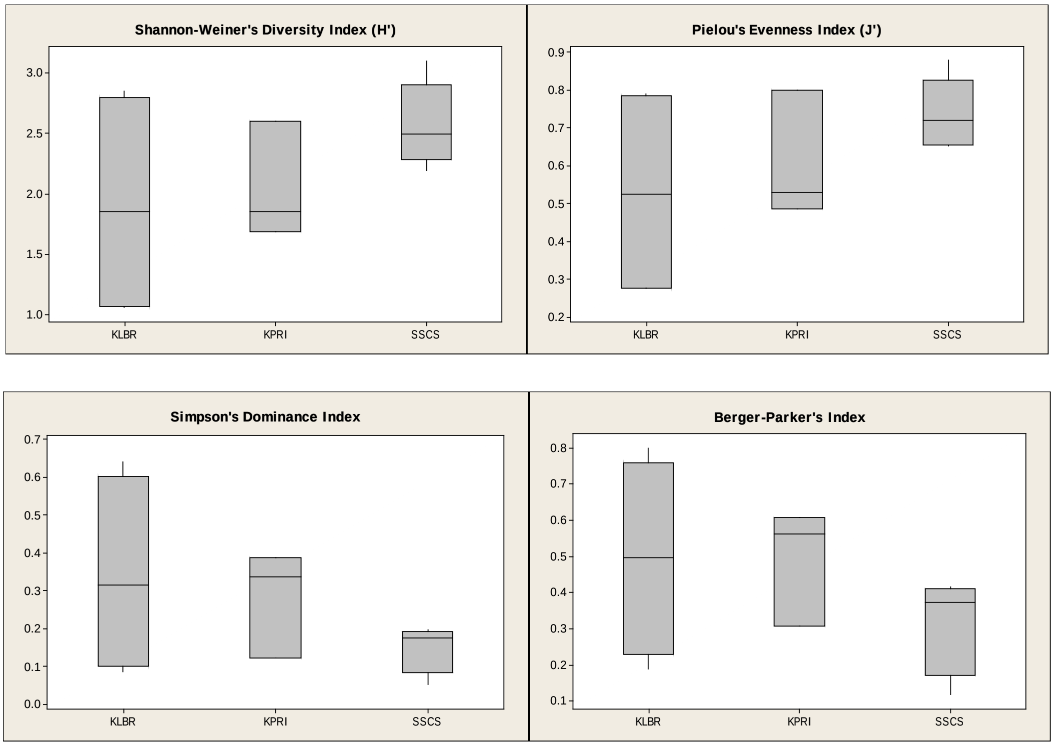

Figure 6: The ecological index based on spatial distribution.

The Shannon's diversity index (H') was significant ($p < 0.05$) and had a negative correlation to temperature and a positive correlation to salinity at a confidence level of $p < 0.1$. Pielou's evenness index (J') had a negative correlation to temperature and a positive correlation to salinity at a confidence level of $p < 0.1$. The Simpons's dominance index (D_s) had a positive correlation to depth and salinity and a negative correlation to temperature at a confidence level of $p < 0.1$, whereas the Berger-Parker's index (D_b) had a positive correlation to temperature at a confidence level of $p < 0.1$ (Figure 7 and Table 1).

Table 1: Pearson correlation coefficients and significance levels between the diversity index and environmental factors.

	De	Te	Sa	pH	DO	Su
S	-0.177	0.112	-0.395	-0.161	-0.242	0.353
H'	0.415	-0.608**	0.473*	0.279	-0.108	-0.115
J'	0.428	-0.562*	0.515*	0.272	-0.027	-0.227
D_s	0.452*	-0.562*	0.453*	0.295	-0.021	-0.208
D_b	-0.406	0.554*	-0.434	-0.270	0.152	0.038

S: richness, H': Shannon-Weiner's index, J': Pielou's evenness index, D_s: Simpson's index, D_b: Berger-Parker's index, De: Depth, Te: Temperature, Sa: Salinity, DO: dissolved oxygen, Su: Substrate.
*$p < 0.1$.
**$p < 0.05$.

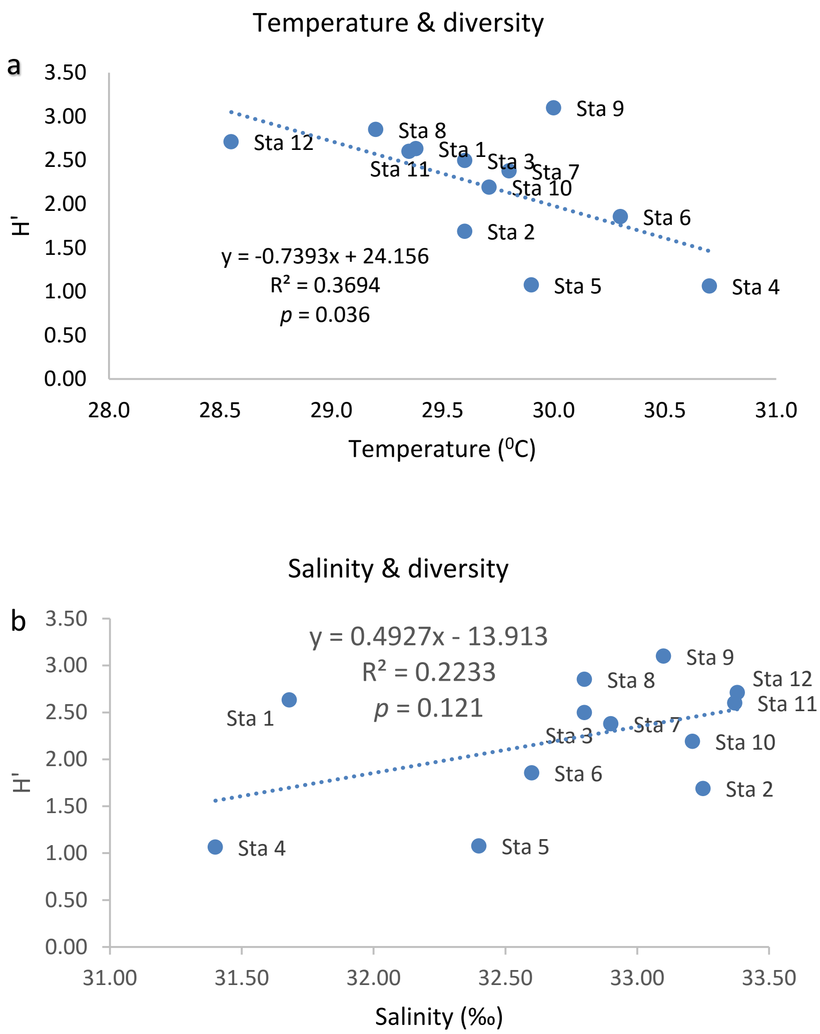

Figure 7: Simple linear regressions of environmental factors versus Shannon-Weiner's diversity index: (a) temperature, and (b) salinity.

The analysis using the Principal component analysis (PCA) resulted in a PC1 which was strongly by indicated the Shannon-Wiener's index (H'), Pielou's evenness index (J'), Simpson's index (D_s), Berger-Parker's index (D_b), and salinity. PC2 was indicated by the type of sediment (substrate), DO, and depth, and PC3 was indicated by temperature, richness (S), and pH (Figure 8 and Table 2).

3.2. Discussion

The level of similarity that was assessed using the Bray-Curtis index divided the distribution of demersal fish resources into three clusters. Demersal fish resources in inshore sites of Kalimantan's western waters (KLBR) were dominated by the Leiognathidae family, with a weight composition of 65.4% of the total catch. The fish *Leiognathus splendens* (the splendid ponyfish) was distributed with a high sweeping weight on the mud-substrate seabed near the beach of Kalimantan's west coast. However, the Leiognathidae family was not found in the observation stations along inshore sites of the eastern of Riau Islands waters (KPRI), which was dominated by a sand-substrate seabed. The coastal waters that had sand substrate were dominated by snappers (Lutjanidae), Tetraodontidae, Haemulidae, and Nemipteridae, whereas offshore sites of the southern of South China Sea (SSCS) was dominated by Nemipteridae, Mullidae, and Serranidae.

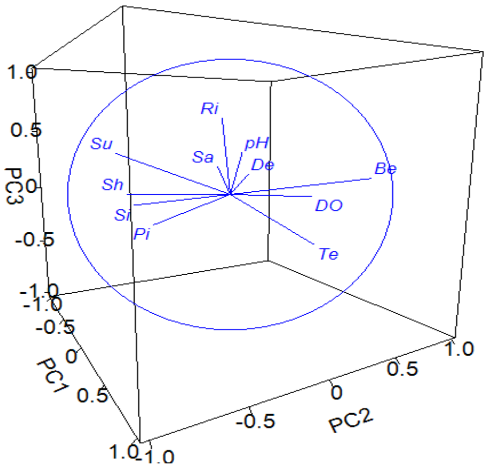

Figure 8: Principal component analysis (PCA) of ecological indices and environmental factors.

Reference [22] stated that community stability could be determined by observing the community structure and the species distribution within the community. A stable community is demonstrated by having a stable species composition and by having relatively little fluctuation in numbers. In addition, [23] stated that changes in species composition could be viewed from dominance, diversity, and species heterogenicity. The high dominance index, and the low diversity index (H') and evenness index (J') indicated disturbance in the stability of the demersal fish community in inshore sites of Kalimantan's western waters (KLBR). Inshore sites of the eastern of Riau Islands waters (KPRI) had a better demersal fish community stability than that of inshore sites of Kalimantan's western waters (KLBR), demonstrated by the higher diversity index (H') and evenness index (J') and the lower dominance index. On the other hand, offshore sites of the southern of South China Sea (SSCS) had much better community stability than the other two clusters. This condition was demonstrated by a higher diversity index (H') and evenness index (J') and a lower dominance index (Simpson's index and Berger-Parker's index) compared to the other two clusters. [24] who conducted a study in the East China Sea collected results in the form of biological indices including richness (S), Shannon's diversity index (H') and Pielou's evenness index (J') which demonstrated an increasing trend further to sea.

Offshore sites of the southern of South China Sea (SSCS) and inshore sites of the eastern of Riau Islands waters (KPRI) have sand and muddy-sand seabeds, whereas inshore sites of Kalimantan's western waters (KLBR) has a seabed with mud substrate which is an effect of sedimentation of sediments from land carried by the many rivers flowing to Kalimantan's west coast. The flow of river water to Kalimantan's west coast carries nutrients from land that affect the temperature and salinity of the waters, enabling only demersal fish, which are euryhalin and eurythermal, to be able to survive these environmental conditions. This was why the Simpson's index (D_s) and Berger-Parker's index (D_b) in inshore sites of Kalimantan's western waters (KLBR) were higher than those of offshore sites of the southern of South China Sea (SSCS) and inshore sites of the eastern of Riau Islands waters (KPRI).

Table 1 and Figure 7 demonstrate how temperature and salinity affect the ecological indices in the southern of South China Sea, especially the Shannon-Weiner's diversity index (H'), Pielou's evenness index (J'), Simpson's dominance index (D_s), and Berger-Parker's index (D_b). This study also revealed that Berger-Parker's index was also affected by depth. The principal component analysis demonstrated a correlation between environmental factors, especially salinity and temperature, and the ecological indices in the southern of South China Sea. This study supports the statement that spatial variability of demersal fish resources in the southern of South China Sea is affected by depth[25,26], seabed sediment type [27], and oceanographical physical factors which are temperature and salinity [28,29].

Table 2: Summary of principal component analysis (PCA) of environmental variables and ecological indices.

Principle component analysis			
	PC1	PC2	PC3
Cummulative percentage variance			
Eigen Value	5.39	2.17	1.21
% Variation	49	19.7	11
% Cum. Variation	49	68.7	79.7
Factor-variable correlations (factor loadings)			
De	-0.300	0.366	0.341
S	0.204	-0.164	0.549
H'	-0.392	-0.233	-0.073
J'	-0.403	-0.157	-0.233
D_s	-0.399	-0.176	-0.163
D_b	0.381	0.262	0.071
Te	0.293	0.147	-0.412
Sa	-0.315	0.260	0.283
pH	-0.207	0.265	0.326
DO	-0.048	0.545	-0.154
Su	0.135	-0.453	0.334

S: richness, H': Shannon-Weiner's index, J': Pielou's evenness index, D_s: Simpson's index, D_b: Berger-Parker's index, De: Depth, Te: Temperature, Sa: Salinity, DO: dissolved oxygen, Su: Substrate.

4. Conclusion

Demersal fish resources were evenly distributed throughout the southern of South China Sea, and was signified by the presence of marker species which divided the waters into three research clusters based on spatial distribution. The community stability level of demersal fish resources in inshore sites of Kalimantan's western waters (KLBR) was lower than those that of the other clusters, whereas offshore sites of the southern of South China Sea (SSCS) had a much better community stability level compared to inshore sites of Kalimantan's western waters (KLBR) and inshore sites of the eastern of Riau Islands waters (KPRI). This study also demonstrated that environmental factors such as depth, sediment type, salinity, and temperature affected the distribution of demersal fish diversity in the southern of South China Sea. `

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