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Assessment of Mangrove Water Quality by Multivariate Statistical Analysis in Suppa Coast, South Sulawasi, Indonesia

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Abstract: Different statistical analysis such as, ANOVA, principal component analysis and multidimensional scale plot were employed to evaluate the trophic status of water quality for three monitoring stations. The present study was carried out to determine the physicochemical parameters of mangrove water of Suppa coast, Pinrang South Sulawesi, Indonesia during September 2011 - April 2012. Seasonal variations of different parameters investigated were as follows: salinity (26.78 - 31.11 ppt), water pH (8.10 - 8.15), substrate pH (5.81 - 6.041), water temperature (29.22 - 30.92), dissolved oxygen (3.37 - 3.89 mg/l), biochemical oxygen demand (2.65 - 4.46) and turbidity (5.44 - 10.67 NTU). Salinity, BOD and turbidity indicated a correlation at $P<0.05$. Based on the test ANOVA, salinity, water pH, water temperatur, DO, BOD and turbidity displayed significant seasonal variation ($P< 0.05$), while substrate pH displayed significant seasonal variation ($P> 0.05$). PCA and MDS identified the spatial and temporal characteristics of trophic stations and showed that the salinity, BOD and turbidity may be major driving factors for deteriorating trophic status of water quality in the Suppa mangroves.

Key words: Mangrove · Water quality · Multivariate analysis · Physicochemical parameters · Suppa Coast

INTRODUCTION

Generally mangroves is a typical species found in areas of tidal and sub-tropical regions around the world. Mangroves form a habitat for many species of flora and fauna, with high density [1-4]. Mangroves are also important to humans for many reasons, including fisheries, agriculture, forestry, building material resources, protection against coastal erosion and hurricanes, the absorption of pollutants and to support coastal fisheries [5-8].

Around the world loss of mangroves has been influential rationally in decades although in some places in the world mangrove forests are still being very broad [9,10]. World wide mangrove forests decreased by 35% over the last two decades of the 20th century [11]. Mangrove forest area has been lost for the construction of municipal, industrial, agricultural land reclamation, timber, charcoal and shrimp farming. Mangroves have declined at an alarming rate in the developing countries, so that mangrove ecosystems may disappear entirely in the next 100 years [12].

Several environmental factors which influence the growth of mangroves is physiographic coast, climate, rainfall, air temperature, tides, waves and currents, salinity and dissolved oxygen [9, 13-16,]. Anthropogenic activities also remarkably influenced the quality of ecosystems in aquatic environments [10, 12, 17-25].

One method that is used for the assessment of mangrove water quality is a multivariate statistical technique. The multivariate statistical techniques such as cluster analysis (CA), principal component analysis (PCA) and non-multidimensional scale plot (MDS) have wiy been used as unbiased methods in analysis of water quality data for drawing meaningful conclusions [26-31]. [32] describes the spatio-temporal control process

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variation and distribution of water quality parameters in the mangrove ecosystem by ANOVA (two-factor without replication), correlation and principal component analysis. In this study, statistical analysis methods ANOVA, Correlation, PCA and MDS were employed to evaluate the trophic status of water quality on Suppa Coast, South Sulawesi, Indonesia. This study was conducted in Suppa Coast, Pinrang Indonesia in order to evaluate the physicochemical parameters of mangrove water environment.

MATERIAL AND METHODS

Water samples taken from the mangrove ecosystem, in Suppa coast, Pinrang, South Sulawesi, Indonesia. Sampling sites as shown in Figure 1. Station 1 (3°58'05.77" S - 119°38'01.76" E) is a mangrove ecosystem, which is located near the mouth of the tributary. The main species found, are *Avicennia marina* and *Sonneratia alba*. Station 2 (3°58'45.72" S - 119°36'27.69" E), is a place, where the fishermen boat tying. The main species found are *Rhizophora mucronata* and *Sonneratia alba*. Station 3 (3°58'28.73" S - 119°35'56.14" E) is the estuary of the waterways of the pond. The main species found, are *Rhizophora apiculata* and *Rhizophora mucronata*

Water samples were collected using a clean glass bucket, transferred to clean plastic bottles and transported to the laboratory on ice and stored in a deep freezer (-20 °C) till analysis. Sample of water pH, salinity, dissolved oxygen (DO) and surface water temperature measured in situ. Water pH was measured using pH meter hand. Salinity was measured using a handheld refractometer (erma). Dissolved oxygen (DO) was estimated by Winkler method [33]. While Biochemical oxygen demand (BOD) and turbidity in the analysis in the laboratory. BOD testing using Winkler-Alkali iodide azide. Turbidity test using nephelometri

Analysis of Variance (ANOVA): Analysis of variance (ANOVA) was employed to evaluate the temporal and spatial variation in concentration of the analysed parameters [32]

Multivariate Statistical Methods: Several analytical techniques are available to extract spatial and temporal patterns and trends in order to provide enhanced understanding and resolve the full information hidden within water quality data [31]. These techniques can be used to identify regions or periods of time with different water quality characteristics, determine whether significant differences in water quality occur between different regions and also to indicate the variables responsible for water quality variations [34].

Principal Component Analysis: PCA is a powerful pattern recognition tool that attempts to explain the variance of a large dataset of intercorrelated variables with a smaller set of independent variables [26]. PCA technique extracts the eigenvalues and eigenvectors from the covariance matrix of original variables. PCA is designed to transform the original variables into new, uncorrelated variables (axes), called the principal components, which are linear combinations of the original variables. The new axes lie along the directions of maximum variance [35,31]. It reduces the dimensionality of the data set by explaining the correlation amongst a large number of variables in terms of a smaller number of underlying factors, without losing much information [36,37]. The PCA can be expressed as

$$Zij = \mathrm{pc}_{i1} x_{1j} + \mathrm{pc}_{i2} x_{2j} + \ldots \mathrm{pc}_{i1} x_{1j}$$

Where z is the component score, pc is the component loading, *x* is the measured value of the variable, *i* is the component number, *j* is the sample number and m is the total number of variables

Non-Multidimensional Scale Plot: MDS is a set of related statistical techniques often used in information visualization for exploring similarities or dissimilarities in data. Ordination plots produced by MDS analyses were used to classify cases into categorical dependent values. One of its objectives is to determine the significance of different variables, which can allow the separation of two or more naturally occurring groups. Non-multidimensional scale plot is proposed for assessing environmental water quality in aquatic ecosystems [38,31].

Data Treatment: The normality of the distribution of each variable was checked by analyzing kurtosis and skewness statistical tests before multivariate statistical analysis is conducted [39]. The original data demonstrated values of skewness ranging from -2.7289 to 7.5732 and kurtosis values ranging -1.9818 to 11.3182, indicating that the data were far from normal distribution. Since most of values of kurtosis and skewness were >0, the raw data of all variables were transformed in the form x'=log 10(x) [31]. After transformation, the skewness and kurtosis values ranged from -2.8373 to 2.1566 and - 1.8606 to 3.5121, respectively, indicating that all the data were in normal distribution or close to normal distribution.

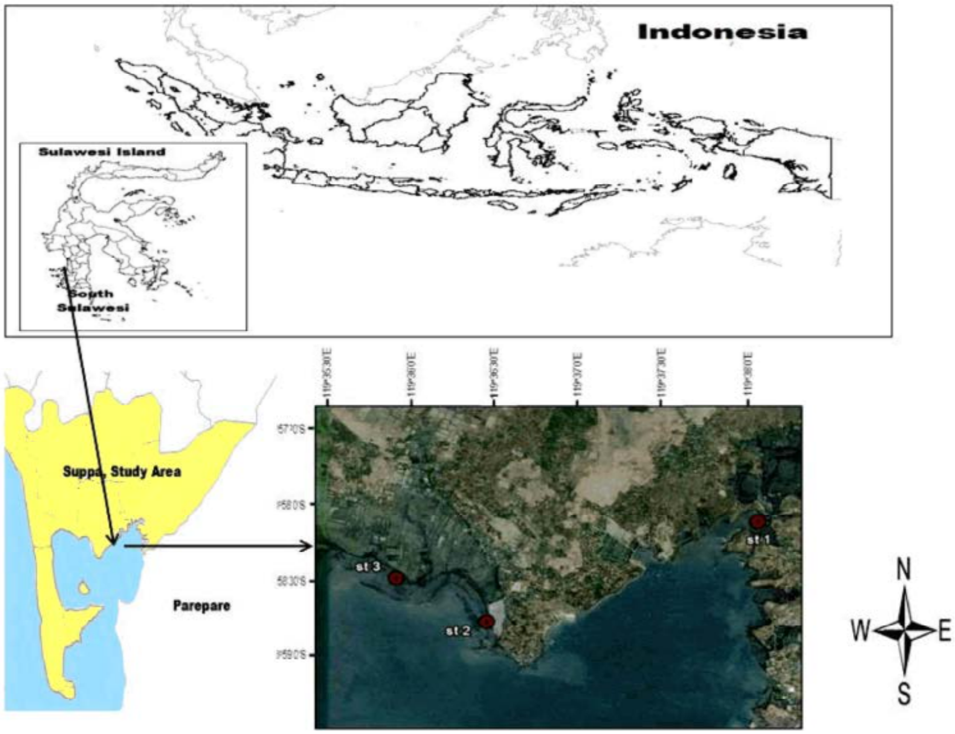

Fig. 1: Monitoring stations in Suppa coast, South Sulawesi, Indonesia

RESULT AND DISCUSSION

Physicochemical Parameters of Water: Salinity displayed significant seasonal variation ($P< 0.05$) and comparatively lower values were detected with its minimum was recorded at station 1, april and maximum at station 3, november). In dry season (September, October and November), salinity average from 30.33 ppt - 31.11 ppt and in rainy season (December, January, February, March and April) average from 26.78 ppt - 29.33 ppt. The lowest salinity values were observed in the entire basin in the monsoon season, where the high variability, especially towards lower values, was related to rainfall, instead, the dry season to an evident salinity increases. Thus the variations in salinity in the study sites were mainly influenced by the rainfall and entry of freshwater. A similar study, also reported by [40,41,31].

Mangroves generally tolerate higher salinity than do nonmangrove plants, but tolerance also varies among the mangroves. For example, Rhizophora mucronata seedlings do better in salinities of 30 ppt, but R. apiculata do better at 15 ppt [42,43]. Sonneratia alba grows in waters between 2 ppt and 18 ppt.

Water pH displayed significant seasonal variation ($P< 0.05$) and comparatively lower values were detected with its minimum was recorded at station 3, april and maximum at station 3, october). The water pH varied from 8.10 to 8.15 (Fig. 3). In dry season water pH average from 8.12 - 8.15 and in rainy season average from 8.10 - 8.14. pH in surface waters remained alkaline throughout the study period at all third stations with maximum during dry season and minimum during rainy season. The low pH observed during the monsoon season is attributable to some factors such as the removal of $CO2$ by photosynthesis through bicarbonate degradation, the dilution of seawater by the freshwater influx, the decrease of the salinity and temperature and the decomposition of organic material (Rajasegar 2003). The high pH values recorded during summer might be due to the influence of seawater penetration and high biological activity [41].

Substrate pH displayed non significant seasonal variation ($P> 0.05$). This suggests that, substrate pH for all stations during the investigation, is no different. Even so comparatively lower values were detected its minimum was recorded at station 2, september and maximum at station 2, november). In dry season, substrate pH average from 5.81 - 6.041 and in rainy season average from 5.85 - 6.04. Substrate pH in the study area, is largely determined by the process of decomposition of the mangrove litter.

Water temperature displayed significant seasonal variation ($P < 0.05$) and comparatively lower values were detected its minimum was recorded at station 2, March

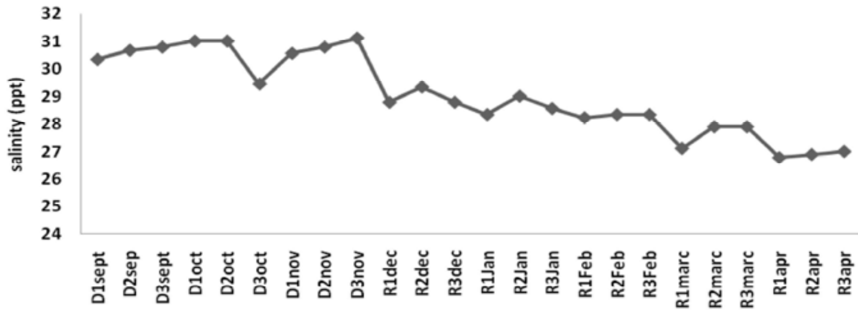

Fig. 2: Seasonal variation of salinity at three stations

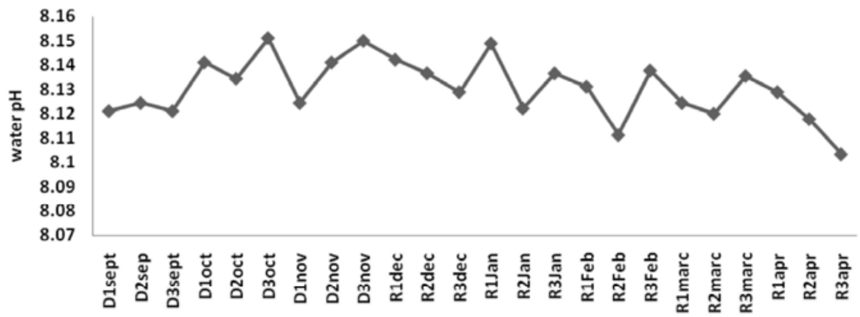

Fig. 3: Seasonal variation of water pH at three stations

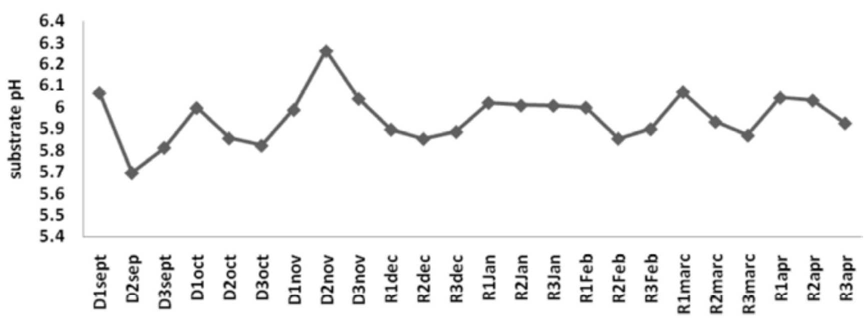

Fig. 4: Seasonal variation of substrate pH at three stations

and maximum at station 3, november). In dry season water temperature average from 29.34 °C - 30.92 °C and in rainy season average from 29.22 °C - 30.55 °C. Water temperature during March was low because of strong land breeze and precipitation but the high temperatures during November could be attributed to high solar radiation [44]

DO displayed significant seasonal variation ($P< 0.05$) and comparatively lower values were detected with its minimum was recorded at station 3, September and maximum at station 3, March. The DO varied from 3.37 mg/l - 3.89 mg/l (Fig. 6). In dry season DO average from 3.37 mg/l - 3.78 mg/l and in rainy season average from 3.49 - 3.89 mg/l. DO come from the results of phytoplankton photosynthesis and diffusion of oxygen into the water. DO earned generally high around the mangroves, in comparison, with a bit away from the mangroves. The increasing of DO in the mangrove forest was caused by oxygen exchanging at the root system of mangrove, particularly Avicennia marina which is the mono-dominant plant. Its root system was 100 centimeters depth from soil surface, spread out and has aerial roots (pneumatophores, upward directed root) in which oxygen can passively diffuse [45] and make this oxygen be easily diffused to water. It is conform to the study of [13] which indicated that DO of obtain the concentration of dissolved oxygen in the mangroves from 1.7 to 3.4 mg / l, lower versus outside mangrove magnitude 4.4 mg / l.

BOD displayed significant seasonal variation ($P< 0.05$) and comparatively lower values were detected with its minimum was recorded at station 2, January and

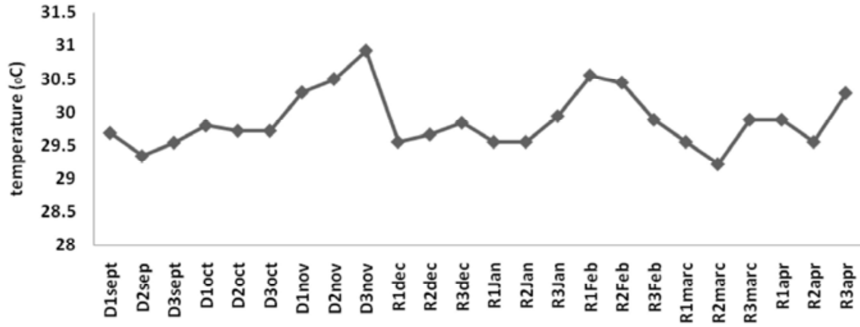

Fig. 5: Seasonal variation of temperature (°C) at three stations

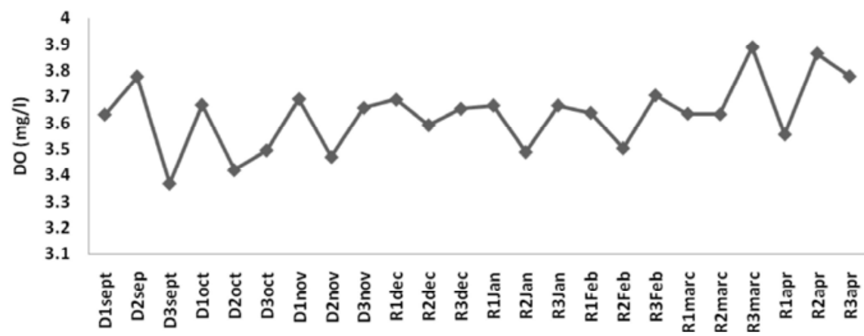

Fig. 6: Seasonal variation of DO (mg/l) at three stations

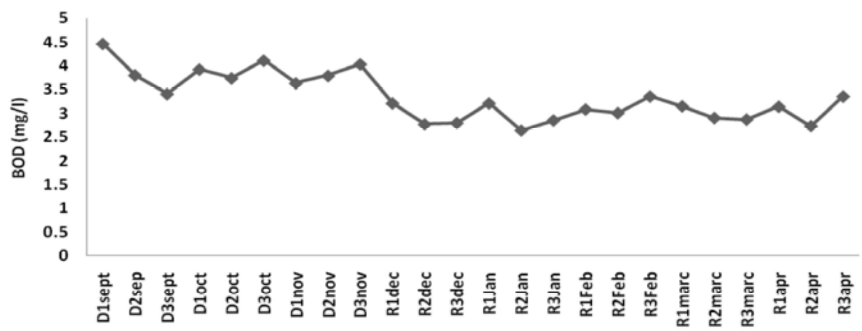

Fig. 7: Seasonal variation of BOD (mg/l) at three stations

maximum at station 1, September. The BOD varied from 2.65 mg/l - 4.46 mg/l (Fig. 7). In dry season BOD average from 3.41 mg/l - 4.46 mg/l and in rainy season average from 2.65 mg/l - 3.36 mg/l. BOD is an indicator of organic pollution in the water. Water with high BOD values??, indicating that the water is polluted by organic matter [46]. If a BOD value of = 2.8 ppm water is not polluted, 3.0 to 5.0 light polluted, 5.1 to 14.9 and = 15 were contaminated heavily polluted [47]. BOD is a parameter that affects the availability of dissolved oxygen and pH values??. If a high BOD content, it will result in shrinkage of dissolved oxygen through the decomposition of organic material under aerobic conditions and a decrease in the pH value of water

Turbidity displayed significant seasonal variation ($P< 0.05$) and comparatively lower values were detected with its minimum was recorded at station 3, November and maximum at station 3, April. The turbidity varied from 5.44 NTU - 10.67 NTU (Fig. 8). In summer turbidity average from 5.44 NTU - 7.78 NTU and in monsoon average from 6.65 NTU - 10.67 NTU. Turbidity in the study area is heavily influenced by several factors, namely the tides, currents and the influence of fresh water into the estuary. Turbidity component is made ??up of mud particles of clay and fine sand.

Table 1 shows the correlation matrix between the physicochemical parameters of water. The significant negative correlation obtained between salinity and

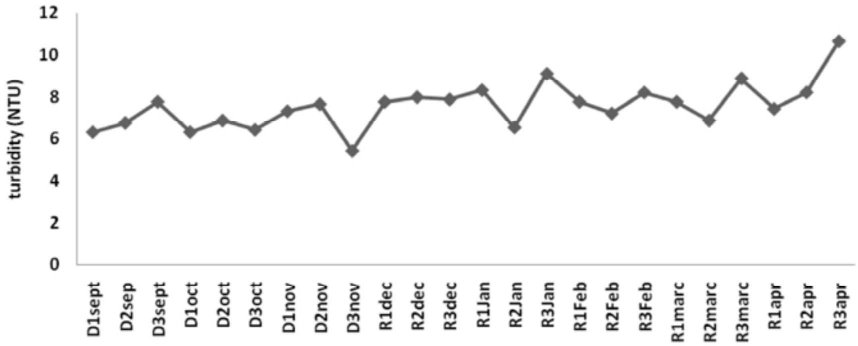

Fig. 8: Seasonal variation of turbidity (NTU) at three stations

Table 1: Correlation coefisient between the physicochemical characteristics of water of Suppa mangroves

	Salinity	Water pH	Substrate pH	Water temperature	DO	BOD	Turbidity
Salinity	1						
Water pH	-0.032	1					
Substrate pH	-0.033	-0.031	1				
Water Temperature	0.103	0.031	0.09	1			
DO	-0.099	-0.004	-0.071	-0.057	1		
BOD	0.357**	0.092	0.102	0.076	-0.103	1	
Turbidity	-0.269**	-0.099	-0.029	0.011	-0.013	-0.195**	1

**P=0.05, level of significant of correlation (two tailed)

Tabel 2: Factor loadings for the analysed parameters

	Component	
	1	2
Salinity	0.890	0.00
Kekeruhan	-0.807	0.00
BOD	0.776	0.162
DO	-0.536	0.00
pHwater	0.503	0.227
pHsubstract	0.00	0.828
WaterTemperature	0.135	0.792

Rotated Component Matriks, Extraction Method: Principal Component Analysis.

Rotation Method: Varimax with Kaiser Normalization.

turbidity indicates that salinity is largely influenced by the turbidity. Thus the variations in salinity in the study sites were mainly influenced by entry of turbidity freshwater by rivers and the fishpond and the rainfall. The significant negative correlation obtained between BOD and salinity indicates that BOD is largely influenced by the salinity. As which has been reported [48] that a there is a significant drop in BOD as a result of increasing salinity. This was directly attributed to the influence of chloride in relation to microbial cellular decomposition

The effect of natural and anthropogenic flux was evaluated using factor analysis with Varimax rotation. A total of 57.24 % of variance was explained by all the two factors. The first factor contributed 37.72 % of the total variance (Table 2) and depicted strong positive loadings on salinity, BOD and water pH. It suggested the fact that rain and drain water from the fish pond was the major parameter controlling the distribution of major elements. Second factor contributed 19.52 % of the total variance exhibiting high positive loadings on substrate pH and water temperature. Decomposition of litter, a major determining factor, of the substrate pH, in the study area. While the water temperature, strongly influenced sunlight and mixing water

Fig. 9 Non-multidimensional scale plot analysis for three stations in different seasons in Suppa mangroves. D1sept dry season station 1, september, D2sept dry season station 2, September, D3sept dry season station 3, September. D1oct dry season station 1, October, D2oct dry season station 2, October, D3oct dry season station 3, October. D1nov dry season station 1, November, D2nov dry season station 2, November, D3nov dry season station 3, November. R1dec rainy season station 1, December, R2dec rainy season station 2, December, R3dec rainy season station 3, December. R1jan rainy season station1, January, R2jan rainy season station2, January, R3jan rainy season station3, January. R1Feb rainy season station 1, February, R2Feb r station 2ainy season, February, R3Feb rainy season station 3, February. R1marc rainy season station 1, March, R2marc station 2, March, M3marc rainy season station 3, March. R1apr rainy season station 1, April, R2apr rainy season station 2, April, R3apr rainy season station 3, April

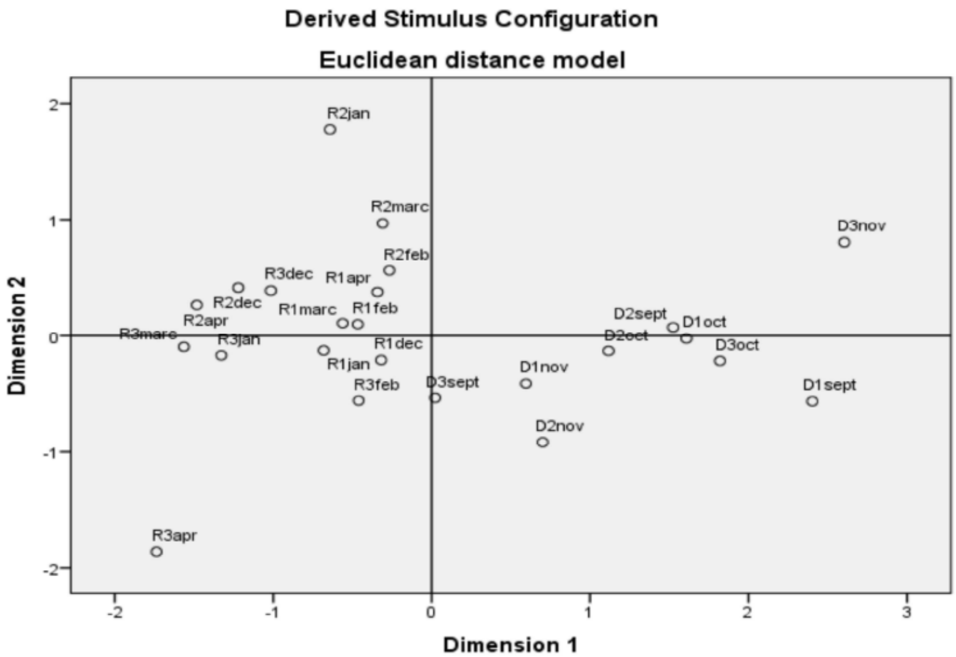

Fig. 9: Non-multidimensional scale plot analysis for three stations in different seasons in Suppa mangroves. D1sept dry season station 1, september, D2sept dry season station 2, September, D3sept dry season station 3, September. D1oct dry season station 1, October, D2oct dry season station 2, October, D3oct dry season station 3, October. D1nov dry season station 1, November, D2nov dry season station 2, November, D3nov dry season station 3, November. R1dec rainy season station 1, December, R2dec rainy season station 2, December, R3dec rainy season station 3, December. R1jan rainy season station1, January, R2jan rainy season station2, January, R3jan rainy season station3, January. R1Feb rainy season station 1, February, R2Feb r station 2ainy season, February, R3Feb rainy season station 3, February. R1marc rainy season station 1, March, R2marc station 2, March, M3marc rainy season station 3, March. R1apr rainy season station 1, April, R2apr rainy season station 2, April, R3apr rainy season station 3, April

Mangrove water quality parameters, evaluated by using MDS, earlier been used to identify which sampling stations were more influenced by the parameters which described each coordinate, as well as to visualize similarities or differences between samples [31]. The similarities among the four monitoring stations were found according to dimension 1 and dimension 2. Figure 9. illustrates that cluster A included D1sept, D2sept, D3sept, D1oct, D2oct, D3oct, D1nov, D2nov dan D3nov (all of the sampling sites from monsoon season) and characterize the negative values in multidimensional plot. Group B included R1dec, R2dec, R3dec, R1jan, R2jan, R3jan, R1feb, R2feb, R3feb, R1marc, R2marc, R3marc, R1apr, R2apr, dan R3apr (all of the sampling sites from summer) and characterize the positive values in multidimensional plot.

Seasonality has an important influence on trophic status of water, the parameters causing dissimilarity between stations 1, 2 and 3 can be seen from Figs. 2, 3, 4, 5, 6, 7 and 8. It is clear from the figure that salinity, BOD and turbidity are the most important parameters causing these dissimilarities. These parameters represent from the domestic sewage, discharge water from the fish pond and fisherman activities around the mangrove areas. Human activities have strong influence on the aquatic environment in the coast Suppa. As was stated above, salinity, BOD and turbidity are the most important surface water quality parameters causing differences among the monitoring stations in region of Suppa mangroves, Indonesia.

Multivariate techniques , PCA and MDS were used to differentiate the trophic status of water quality in the monitoring sites. PCA can support more information about trophic status of water quality and corresponding factors. MDS approach can further identify the differences among the trophic status of water quality in different sites and can distinguish the corresponding driving factor. Based on the MDS plot, salinity, BOD and turbidity may be major driving factors for deteriorating trophic status of water quality. From the above discussion, we can say that MDS and PCA are a useful tool to analyze the pollution source and monitoring sites. It can offer information to identify polluted sites and help in the decision making on controlling of water pollution.

CONCLUSION

In this case study, ANOVA, PCA and MDS is employed to evaluate the temporal and spatial variation in concentration of the analysed parameters. Based on the test ANOVA, salinity, water pH, water temperatur, DO, BOD and turbidity displayed significant seasonal variation ($P< 0.05$), while substrate pH displayed significant seasonal variation ($P> 0.05$). The effect of natural and anthropogenic flux was evaluated using PCA analysis with Varimax rotation. The first factor depicted strong positive loadings on salinity, BOD and water pH. It suggested the fact that rain and drain water from the fish pond was the major parameter controlling the distribution of major elements. Second factor high positive loadings on substrate pH and water temperature. Decomposition of litter, a major determining factor, of the substrate pH, in the study area. While the water temperature, strongly influenced sunlight and mixing water. Based on the MDS plot, salinity, BOD and turbidity may be major driving factors for deteriorating trophic status of water quality. Thus, this study illustrated the usefulness of multivariate statistical techniques for the analysis and interpretation of complex data set and water assessment.

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