

Application of Macrobenthic Faunal Indices in Assesssing the Ecological Quality Status of Laloi Lagoon of Ghana

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Abstract
The aim of this study was to assess the macrobenthic fauna structure and use its indices as a tool for characterizing the ecological state of the Laloi lagoon. Thus, a field assessment of the benthos in the Laloi lagoon was carried in January 2012. Four replicate samples were taken at each station contained in three zones and analysed for their structure and composition. Twenty-one (21) species of macrobenthos belonging to 19 genera were identified. The highest number of species belonged to Polychaetes (15 species) followed by Bivalves (6 species) and 1 species of Gastropod. The grain size of sediments and total organic matter as essential factors in distribution and population diversity of macrobenthos communities were also analysed. The results showed that all of the stations were characterized by medium sand to very fine sand. Shannon-Wiener index (H'), species richness (S) and Pielou's evenness were calculated and they revealed a high species diversity with variability in abundance within stations. The ecological indices, such as (AMBI, M-AMBI, BENTIX and H') were also applied to the available benthic species data to determine the ecological status of the lagoon. AMBI, M-AMBI, H' and BENTIX gave different results regarding the boundaries for High, Good and Moderate and it was worse when applying H' and BENTIX. However, the index AMBI provided a more suitable evaluation of EcoQS corresponding to 'slightly polluted' lagoons in compliance with univariate community indices.
Keywords: Macrobenthic Faunal Indices, Laloi Lagoon, Ecology

1. Introduction

Coastal lagoons can be defined as areas of relatively shallow water that have been partly or wholly sealed off from the sea by the formation of depositional barriers, usually of sand or shingle, built up above high-tide level by wave action (Bird, 1994). These areas are often of considerable interest as natural resources, largely because of visiting wintering and migrating birds and/or the flora and fauna of the shingle (Barnes, 1991), but they also provide significant food resources, and local fishing and aquaculture constitute one of the oldest forms of coastal resource exploitation (Ardizzone *et al*., 1988).

Depending on their geomorphological and hydrological status, these shallow coastal environments may be characterized by frequent fluctuations in environmental parameters on a daily and seasonal basis, which cause changes in the structure and distribution pattern of organisms. In this sense, coastal lagoons can be considered as harsh and naturally stressed habitats (Barnes, 1980). In some cases, the change in the environmental parameters in lagoons is severe (Guelorget and Perthuisot, 1992) and leads to dystrophic crises (extremely high levels of temperature and salinity combined with low oxygen availability both in the water column and the surface sediments). Although this extreme natural disturbance often results in instant destruction of great numbers of individuals, especially those entering the lagoon to feed, the ecosystem recovers quickly once the crisis is over (Guelorget and Perthuisot, 1992). However, various human activities in lagoons have a severe impact on the macrozoobenthic community structure, and it has been questioned whether these drastic changes are reversible (Barnes, 1991).

Benthic zone of a water body refers to the sediment at the soil-water interface (Mader, 2003). According to Tait (1981), the sessile and attached plants and animals and all the creeping and burrowing forms are collectively known as benthos. Other authors also have various descriptions of benthos. Ziegelmeier (1972) simply refers to the bottom fauna as benthos. Similarly Wetzel (2001) states that benthos now uniformly applies to animals associated with substrata. They live in (infauna) or on (epifauna) the bottom sediments (Levinton, 1995).
Classifications of benthic fauna are diverse. Benthic organisms can be classified based on their sizes. According to Gerlach (1972), all animals which are retained in a sieve with a mesh width of 0.5 – 2.0 mm are classified as macrofauna, and those which pass through the mesh as microfauna. Meadows and Campbell (1988) confirmed that benthic animals measuring 20 cm or larger are megafauna, macrofauna are between 20 cm – 0.5 mm, meiofauna falls within 0.5 mm and 50 µm and microfauna as those with the size range of 50 µm – 5µm.

Levinton (1995) described meiofauna as those organisms or animals that are smaller than 0.5 mm but larger than the microfauna which are less than 0.1 mm. According to Ziegelmeier (1972), all animals that are retained in a sieve with a mesh size of 1.0 × 1.0 mm are macrobenthos and all smaller ones as microbenthos.

Macrobenthic fauna are important integral part of any aquatic ecosystem. The benthic fauna are responsible for the cycling of materials in the aquatic ecosystem and plays an important part in food chains as do the plankton and nekton in the pelagic zone (Ziegelmeier, 1972). This is because they constitute important secondary and tertiary producers in the trophic chain including breaking down detritus which is a primary producer in the aquatic habitats.
Many of the Ghana's lagoons are perceived to be polluted. Increasing exploitation of lagoons and its resources are some of the causes of the degradation and increased concerns about the long term sustainability of such systems. The basic issue is to define the threshold in which an ecosystem can function and provide the community with services, while guaranteeing next generations' potential right (Pinto *et al.,* 2009). Environmental services such as fishery can be sustained when sound methods and protocols are available to survey the status and trends in ecosystems.
Most work to assess pollution, however, makes use of single parameters such as physicochemical parameters and fish. Such parameters are usually very variable and subject to many assumptions (McCormick and Peck, 2000). Macrobenthos are however, better indicators because of their sedentary lifestyle and long residency periods in particular habitats.

The selection of only one or a few indicators, narrows the focus of the ecological management program, and oversimplifies understanding of the spatial and temporal interactions. This simplification often leads to poorly informed management decisions. The development of a mix of measures which give interpretable signals is therefore necessary to be used to track the ecological conditions at reasonable cost, and cover the spectrum of ecological variation.

2. Materials and Methods

2.1 Study Site
The Laloi lagoon falls within latitude 5˚42'52.81N and 5˚41'25.65N, and longitude 0˚4'31.533 and 0˚3'59.264 E. It is located in Prampram and enters the sea at Kpone in the Tema Municipality in the Greater Accra region of Ghana. The lagoon is open all year round and it is not fished on Tuesdays. The main fish gears employed in the lagoon are cast nets, drag nets and traps, used mainly for crabs. The lagoon serves as a source of fish to the inhabitants of the community. Different species of fine fishes serve as a source of protein. These include *Sarotherodon melanotheron, Caranx hippos, Epinephelus aeneus, Ethmalosa fimbriata, Syacium microrum* and *Lutjanus goreensis.* There are strands of mangroves which are at various stages of degradation. Associated with the mangroves, is the succulent grass *Sesuvium portulacastrum* and *Paspalum vaginatum*. The Laloi lagoon also serves as a link between Kpoi-Ete and Kpone. The Gao Lagoon between Manhean and Kpone flows into the Laloi lagoon. It is perceived to be a female goddess called Laloi Baake according to the locals. Figure 1 shows a map of the Laloi lagoon indicating the various stations that were sampled.

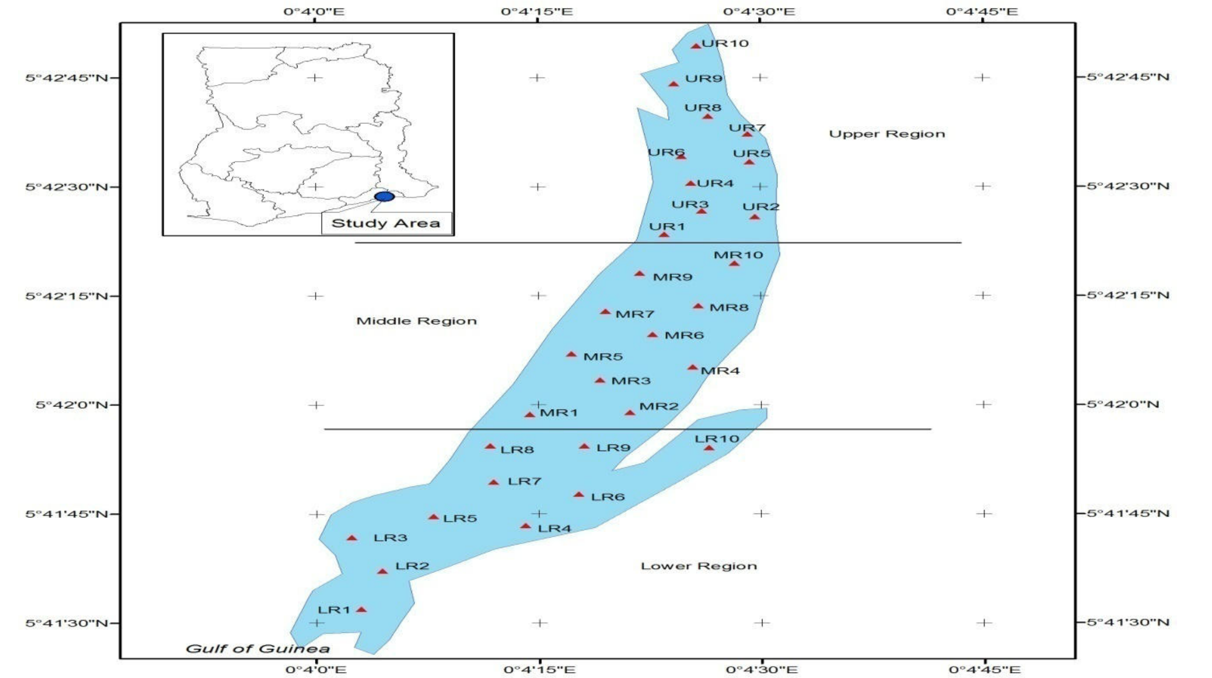

Figure 3: Map showing study area

2.2 Sampling Protocol

In order to study the spatial macrobenthic fauna structure of Laloi lagoon, 30 stations were selected (10 stations each from the lower, middle and upper reaches of the lagoon). Sampling was carried out in January 2012.

Samples for studying the benthic macrobenthos of each station were collected using a 0.0762 m diameter polyvinylchloride (PVC) pipe corer which was pushed into the sediment to a depth of about 0.25m. Three cores (total surface area = $0.0136m^2$) constituted a replicate and at each station, four replicate samples were taken to ensure adequate sample representation. Samples were sieved through a 0.5mm mesh to get rid of excess silt and sand. The retained materials on the sieve were put in a bottle and fixed in 10% buffered formaldehyde and stained with Bengal Rose to facilitate sorting and identification later in the laboratory. An additional core was taken at each station for determination of sediment characteristics including particle size analysis and organic matter content. The sediment samples were stored in labelled polyethene bags. These soil samples will be air-dried and used for granulometric analysis (i.e., sand, silt, and clay fractions). Some aquatic water variables (e.g., pH, dissolved oxygen, salinity and water temperature) were measured *in situ* at all stations using a multi - parameter probe.

2.3 Laboratory Processing of Samples

In the laboratory, the benthic organisms were thoroughly washed to get rid of excess formalin. Macrobenthos were sorted (i.e., picking the organism from the sediment) and preserved in 70% ethanol with glycerol. The organisms were later classified into broad morphological functional group level and consequently identified into species level where possible. The number of each species was counted and recorded.

The sediment samples for granulometry were air dried and prepared for mechanical analysis according to Clark and Haderlie (1960). Saturated sodium chloride was used to wash the sediments thoroughly in order to disperse them. The sediment samples were again air-dried and later oven dried at a temperature of 105 ºC until a constant weight was attained. 100 grams of each sample was then weighed into a ceramic dish (this was recorded as weight of dry soil). These oven-dried sediments were then put in a furnace at a temperature of 450 ºC to burn the organic matter. The sediments were then reweighed after burning (this weight was recorded as weight loss on burning). The percentage organic matter of the soil was calculated as follows:

$$\frac{\text{Weight loss on burning}}{\text{Weight of dry soil}} \times 100$$

The sediments were then separated into the different fractions using the Wentworth sieves. Sieves of different meshes were stacked together with the larger meshes above the smaller ones. 100 grams of the prepared soil sample was then poured into the top sieve and the whole stack shaken vigorously to disperse the various grain sizes. Particles larger than any particular sieve mesh was retained on that mesh size. The contents of each sieve was carefully turned out onto a separate sheet of paper, weighed and then expressed as a percentage of the whole soil. The percentage composition of the content of each sieve (fraction) was calculated as follows:

$$\text{Percentage composition} = \frac{\text{Weight of fraction}}{\text{Dry weight of sample}} \times 100$$

2.4 Data Analysis

To determine the sediment grain sizes, percentage cumulative weights of the different fractions were plotted against particle size in a semi-logarithmic curve and the mean particle size is extrapolated at the 50 % level (Tait, 1981). According to Tait (1981), the particles in the sediment can be classified according to size using the Wentworth Classification of Particle Grades and Phi Scale. The Wentworth scale of particle sizes is geometric, giving smaller intervals towards the finer end of the range. The corresponding 'phi scale' substitutes a logarithm for particle diameter ($\phi = \log_2$ of particle size in mm), converting the unequal steps of the Wentworth scale into an arithmetic series of equal intervals, thereby simplifying graphical and statistical treatment.

Macrobenthos data obtained was subjected to multivariate analysis utilizing the PRIMER v.6.0 software package (Plymouth Routine In Marine Ecological Research). Since data obtained (physico-chemical parameters) had different units of measurements, all data of the physico-chemical variables were standardized and later normalized using the PRIMER software. Macrobenthic fauna community structure and dynamics were investigated using the PRIMER software by means of taxa abundance, diversity (Shannon-Wiener H'), evenness (Pielou's) and richness (Margalef's d'). In order to describe the connections and differences in community structure between stations, a fourth-root transformation (to stabilize the variance) was applied to macrofauna abundance data and dendrograms were produced based on the Bray-Curtis similarity indices of species composition between stations. By this method, stations with similar benthic macrofauna abundance and composition are expected to cluster together. This index was chosen because it is not affected by difference in sample size and this index does not consider the double absences frequently found in the data. Densities of the groups of macrobenthos encountered were determined using a total surface area of $1.632m^2$. That is, three cores (total surface area = $0.0136m^2$) x 4 replicates x 30 stations. ($0.0136\ m^2 \times 4 \times 30 = 1.632\ m^2$)

Differences between the macrobenthic communities of the different stations were further investigated by means of non-metric multidimensional scaling (nmMDS) ordination. The fauna group contributing to dissimilarity between samples observed in the dendrogram was investigated using similarity percentage procedure (SIMPER). The results obtained assisted in interpretation of the faunal changes responsible for the pattern observed in the ordination. The contribution of each species to the average similarity within each group was also examined. Principal Component Analysis (PCA) of the abiotic water variables was also performed to determine their effect on the structure and abundance of macrobenthic fauna in the Laloi lagoon.

Finally, the classification of ecological quality status, was done by AMBI index following the guidelines of Borja and Muxika (2005) and use of version 5 of the software with March 2012 species list and Bentix index as an Add-in to excel (version 11).

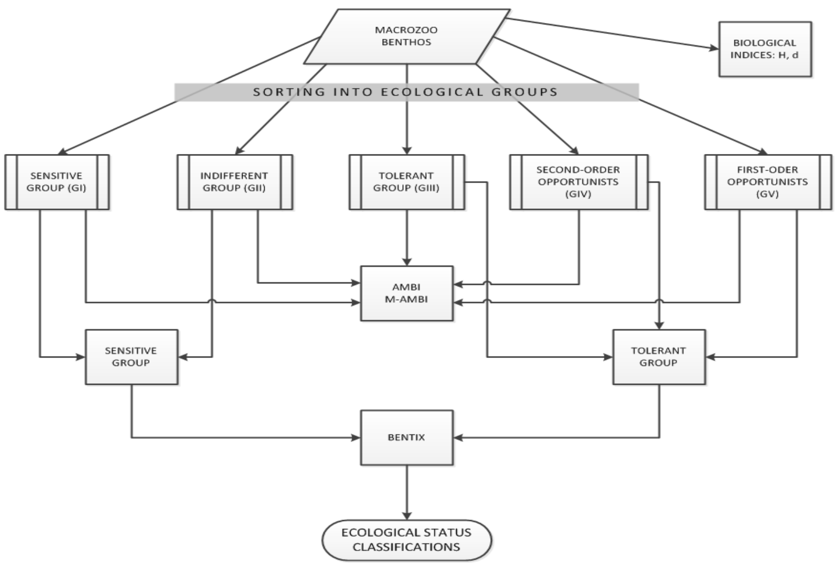

Figure 4: Flow diagram of ecological classification processes using benthic invertebrate fauna.

3. Results and Discussions

3.1 Abundance and Taxa Dominance

From Table 1, a total of 2,206 individuals belonging to 21 genera of macrofauna were identified. These species represented taxa including Polychaetes, Bivalves and a Gastropod. Highest number of species belonged to Polychaetes (15 species), Bivalves (5 species) and 1 species of Gastropod. Polychaetes contributed a total of 1,958 individuals representing 88.8% of the total abundance, Bivalves contributed a total of 153 individuals representing 6.9% and Gastropod contributed 95 individuals representing the remaining 4.3% of the total abundance. Among all the species, Figure 3 revealed that *Glycera convoluta* (a polycheate) contributed the highest number of individuals of 648 representing 29% of the total number of individuals. *Tivela tripla* (a bivalve) contributed the least individuals.

Table 1: Taxa abundance and Density

TAXA	ABUNDANCE	DENSTY(ind./m^2)	% ABUNDANCE
Polychaetes	1958	1200	88.8
Bivalve	153	94	6.9
Gastropod	95	58	4.3
TOTAL	**2206**	**1352**	**100**

Densities were determined using a total surface area of 1.632m^2. That is, three cores (total surface area = 0.0136m^2) x 4 replicates x 30 stations. (0.0136 m^2 x 4 x 30 = 1.632 m^2)

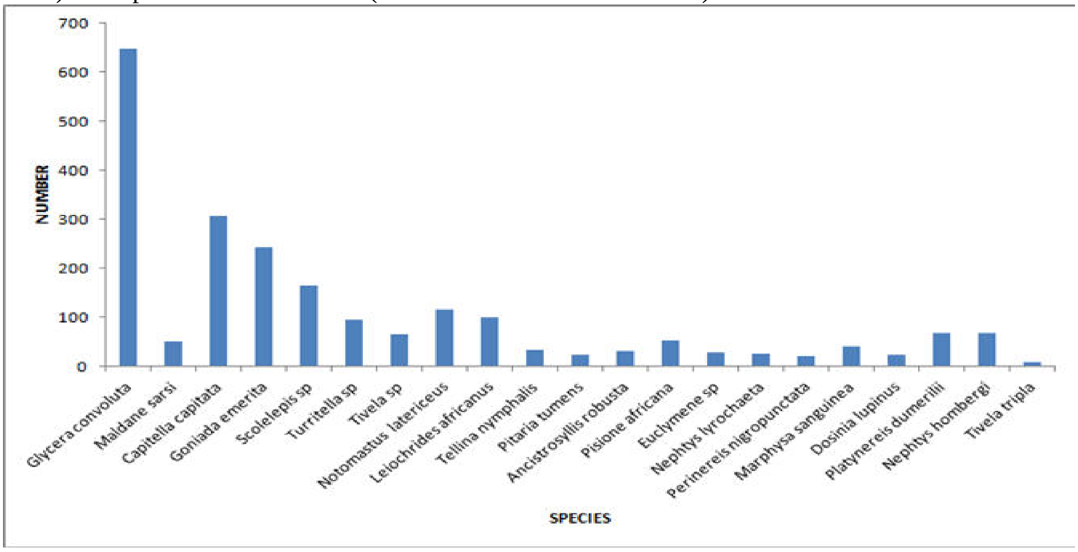

Figure 5: Total abundance of species in the study area for the sampled station

3.2 Community Structure

Figure 4 shows dendrogram of Bray-Curtis similarity of stations based on benthic macrofaunal data. Six distinct zones could be distinguished at the similarity level of 23%. The station clustering indicates stations with similar community structure. Three of the station clusters were formed at Bray-Curtis similarity level of 60%. Cluster II consists of stations UR6, UR5, MR10, MR5, MR3, MR2, UR7 and LR6 indicating mixture of stations from all the zones. Cluster III also consists of stations LR10, LR4, LR3, LR9 and UR4 while cluster IV comprises stations LR8 and LR2. The structure revealed that the stations from the lower reaches (LR) were significantly different from the mid reaches (MR) and the upper reaches (UR).

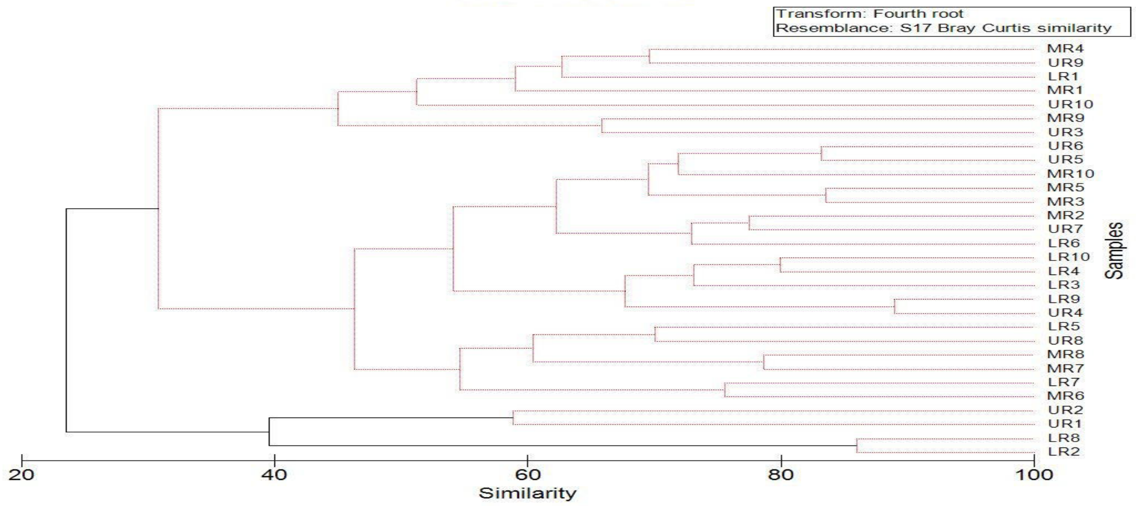

Figure 6: Dendrogram of complete linkage clustering of Bray-Curtis similarity of benthic macrofauna among stations.

Figure 5 shows the MDS ordination plot of species abundance data. This further revealed the similarity of stations based on their fauna abundance and composition among stations. At a similarity level of 46, two main groups are formed. Stations LR8 and LR2 form one group and the other stations also form another group. Stations LR8 and LR2 are very similar in terms of faunal composition and abundance. Within the bigger group, there are still further similarities between stations at a similarity level of 60.

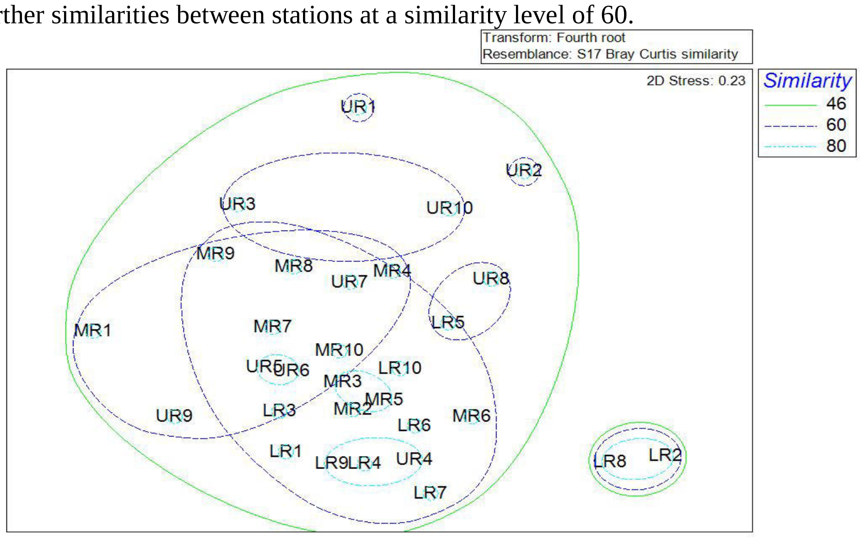

Figure 7: Multidimensional Scaling (nmMDS) of stations in terms of macrofauna abundance and composition.

Principal Component Analysis was carried in order to find out the environmental parameters which explained the variations in the fauna abundance and composition. From Table 2, the first principal component (PC1) explained 31.3% of variance.

Temperature and organic matter showed negative variations on PC1. Salinity, DO, grain size and pH exhibited positive variations on this axis, an indication that they influenced faunal assemblage. PC2 explained 30.1% of the variability and was negatively contributed by DO, grain size and organic matter. Temperature, salinity and pH were positively loaded on this axis. PC3 and PC4 accounted for 18.7% and 9.8% of the variability respectively. It is evident from Figure 6 that, grain size, salinity, organic matter, temperature and DO were the major abiotic variables influencing macrobenthic faunal assemblage patterns in the lagoon.

Table 2: Eigenvalues of Principal Component Analysis

PC	Eigenvalues	%Variation	Cum.%Variation
1	1.88	31.3	31.3
2	1.8	30.1	61.3
3	1.12	18.7	80
4	0.59	9.8	89.9
5	0.447	7.5	97.3

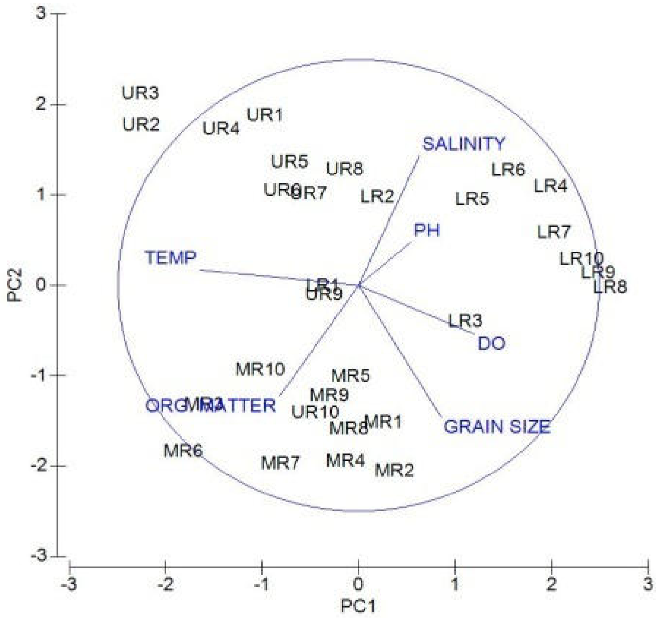

Figure 8: Principal Component Analysis between biotic and abiotic variables

3.3 Species Diversity

The Shannon Wiener Index (H') calculated recorded a mean value of 2.051 with the highest value of 2.612 at Station MR10 and a least value of 1.200 recorded at Station MR5. Margalef's species richness index (d) showed a least value of 1.193 observed at Station LR2, highest value of 3.636 at Station MR10 with a mean value of 2.571. Pielou's index (J) had the least value of 0.455 recorded at Station MR5 and the highest value recorded at Station MR10. The Pielou's index (J) recorded a mean value of 0.846. The H', J and d values for each station are shown in Figures 7 and 8.

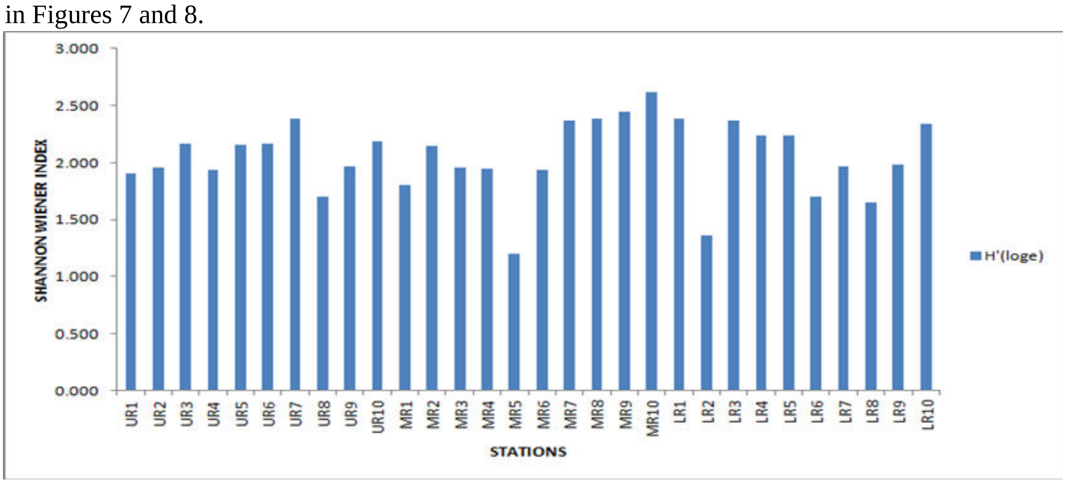

Figure 9: Shannon Wiener diversity index along stations

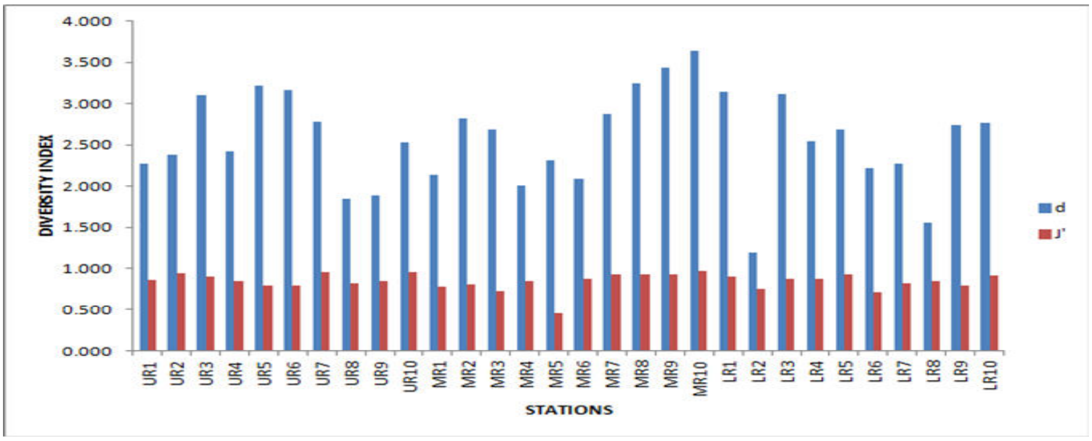

Figure 10: Species richness and evenness values along stations

3.2 Ecological Quality Assessment

Table 3: BENTIX, AMBI and M-AMBI values and respective classes of EcoQS applied at each station. A: individuals (%) without Ecological group (EG) assignment by applying BENTIX, B: individuals (%) without EG assignment by applying AMBI

STATIONS	H'	EQS	BENTIX	EQS	AMBI	EQS	M-AMBI	EQS	A	B
UR1	1.90	POOR	2.47	POOR	2.63	GOOD	0.72	GOOD	35.20	5.90
UR2	1.96	POOR	1.79	BAD	2.84	GOOD	0.69	GOOD	52.63	0.00
UR3	2.17	POOR	0.88	BAD	2.59	GOOD	0.80	HIGH	56.00	12.0
UR4	1.94	POOR	1.71	BAD	2.27	GOOD	0.77	GOOD	24.39	9.80
UR5	2.16	POOR	1.82	BAD	3.26	GOOD	0.83	HIGH	40.26	10.40
UR6	2.16	POOR	2.29	POOR	3.24	GOOD	0.83	HIGH	24.10	9.60
UR7	2.39	POOR	2.04	POOR	2.57	GOOD	0.85	HIGH	36.54	0.00
UR8	1.69	POOR	1.36	BAD	2.59	GOOD	0.67	GOOD	59.09	0.00
UR9	1.96	POOR	2.07	POOR	3.20	GOOD	0.70	GOOD	26.89	6.70
UR10	2.19	POOR	1.94	BAD	2.10	GOOD	0.82	HIGH	48.57	0.00
MR1	1.79	POOR	2.85	MODERATE	1.98	GOOD	0.77	HIGH	33.33	4.50
MR2	2.14	POOR	2.32	POOR	2.50	GOOD	0.87	HIGH	20.00	2.00
MR3	1.96	POOR	2.32	POOR	2.02	GOOD	0.90	HIGH	12.50	4.30
MR4	1.95	POOR	2.58	MODERATE	2.02	GOOD	0.79	HIGH	15.73	0.00
MR5	1.20	BAD	2.03	POOR	1.89	GOOD	0.78	HIGH	8.66	1.10
MR6	1.93	POOR	1.61	BAD	2.71	GOOD	0.71	GOOD	36.96	10.90
MR7	2.37	POOR	1.78	BAD	1.95	GOOD	0.92	HIGH	44.62	12.30
MR8	2.39	POOR	1.40	BAD	2.53	GOOD	0.88	HIGH	45.00	20.00
MR9	2.45	POOR	2.23	POOR	2.09	GOOD	0.94	HIGH	34.09	25.00
MR10	2.61	POOR	2.26	POOR	2.74	GOOD	0.94	HIGH	38.30	14.90
LR1	2.38	POOR	2.89	MODERATE	2.85	GOOD	0.87	HIGH	22.22	20.60
LR2	1.36	BAD	2.03	POOR	4.98	MODERATE	0.40	MODERATE	28.79	15.20
LR3	2.37	POOR	2.36	POOR	2.68	GOOD	0.90	HIGH	17.98	15.70
LR4	2.24	POOR	2.23	POOR	3.27	GOOD	0.80	HIGH	18.92	9.00
LR5	2.24	POOR	1.90	BAD	2.82	GOOD	0.79	HIGH	34.15	0.00
LR6	1.69	POOR	1.60	BAD	2.76	GOOD	0.72	GOOD	22.22	2.20
LR7	1.97	POOR	2.30	POOR	2.11	GOOD	0.81	HIGH	22.22	14.80
LR8	1.65	POOR	2.60	MODERATE	3.13	GOOD	0.60	GOOD	38.30	23.40
LR9	1.99	POOR	2.07	POOR	2.08	GOOD	0.83	HIGH	18.18	10.90
LR10	2.33	POOR	1.82	BAD	2.46	GOOD	0.87	HIGH	32.89	11.80

The application of the indices AMBI, M-AMBI, H' and BENTIX produced uncorroborated results in the ecological status assessment. Comparing pairs of indices, a higher number of matching among classes was found between AMBI and M-AMBI. These two indices placed the study site between an ecological quality status classification of high and good. The BENTIX index also showed an agreement in ecological status assessment with the Shannon Wiener diversity index. Out of the total of 30 stations, the BENTIX index classified 14 stations as poor, 12 as bad and 4 stations as moderate. The Shannon Wiener diversity index classified all the 30 stations as poor. The AMBI index also identified all the stations except LR2 as good. Station LR2 was classified moderate. Finally, the M-AMBI index classified 21 stations as high, 8 as good and 1 as moderate. A summary of the BENTIX, AMBI and M-AMBI values and respective classes of EcoQS applied at each station is shown in Table 3.

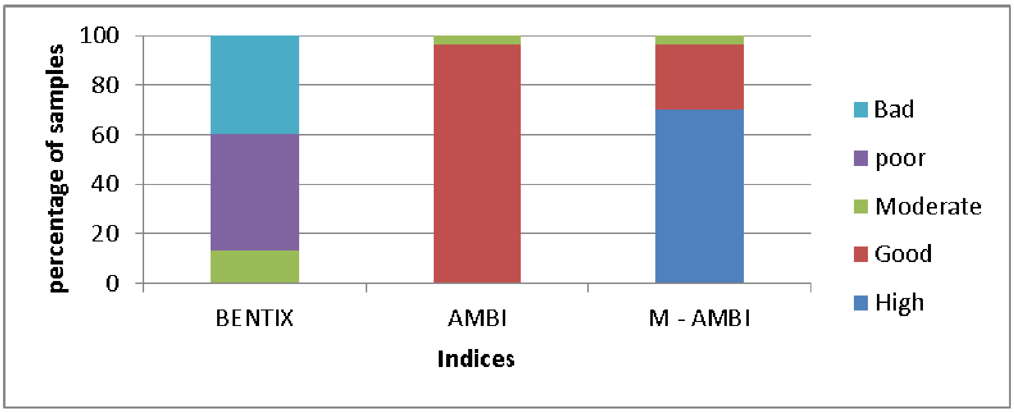

Figure 11: Percentages of samples from Laloi lagoon for each class of EcoQS according to BENTIX, AMBI and M-AMBI

In general, according to BENTIX, most of stations are classified as heavily polluted (46.7%), moderately polluted (13.3%) and Azoic (40%). For AMBI, slightly polluted (96.7%) and moderately polluted (3.3%). Finally for M–AMBI, a percentage of 96.7% of the total number of stations are classified as Normal (high and good) and 3.3% of the stations are classified as moderately polluted. These results are summarized in Figure 9 which shows the percentages of samples for each class of EcoQS according to the benthic indices.

4. Conclusion

In this study, AMBI, M-AMBI, H' and BENTIX used in the ecological status classification gave different results regarding the boundaries for High, Good and Moderate and it was worse when applying H' and BENTIX. However, the index AMBI provided a more suitable evaluation of EcoQS corresponding to 'slightly polluted' lagoons in compliance with univariate community indices. Although the indices provided varying results, this work provides important information to the application of relatively new ecological indices, mostly applied in marine ecosystems, in assessing lagoonal ecosystems. Spatially, stations located in the middle portions of the lagoon presented the highest number of individual macrofauna.
The amount of organic matter and mud in the lagoon was quite low. The results of the sediment grain size analysis indicated that the texture of soil in this area is mostly consisting of medium sand to very fine sand.

The results of this study allows to conclude that ecosystem health can be assessed through the existing diversity of benthic macrofauna which can be evaluated by considering diversity indices and the response of the existing communities to organic matter enrichment.

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