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Effect of Water Quality on Zooplankton in Mangrove Areas of Munroe Island, Kerala

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***Abstract*:** The present study was directed to evaluate the influence of water quality variables on selected zooplankton groups in the Munroe Island. Ten sampling stations were selected and zooplankton samples were collected with WP net (200 µm). Fourteen water quality parameters were considered for the analysis to recognize their influences on zooplankton community. The pH ranged from 6.90 to 7.53.The level of solids, conductivity, salinity, total alkalinity and total hardness was high in Pattamthuruthu when compared to other stations. Palliyanthuruthu registered a minimum DO.The BOD and COD varied from 0.17 to 0.876, 9 to 19 respectively. The Pezhumthuruthu shows maximum abundance of zooplankton (72745No/m^3) and minimum at Kidapram I (8002No/m^3). Among the zooplankton communities, copepoda showed maximum abundance (32740No/m^3) and chaetognatha minimum (3No/m^3).The water quality variables such as total hardness, total alkalinity, salinity, temperature, electrical conductivity and total dissolved solids tend to increase towards the sampling stations adjacent to the Ashtamudi estuary. The variation in zooplankton abundance and hydrological features clearly corroborate the influence of Ashtamudi estuary and similarly the influence of Kallada River on Villimangalam , Kidapram II and Kidapram I was also reflected during the study period. The zooplankton abundance in Munroe Island was significantly influenced by the variations in water quality due to various natural as well as anthropogenic stresses.

***Keywords*:** Water quality, Zooplankton, Anthropogenic activities, Munroe Island

The Munroe Island is the combination of eight small islands, located at the confluence of two water bodies - Ashtamudi Lake and Kallada River. Due to its rapid settlement, the island is known as 'sinking island' (Jha and Sahib 2016). At present the ecological condition of Munroe Island is under risk, as it is facing land erosion. Regrettably, the land erosion occurred mostly due to the destruction of mangrove ecosystems. The fluctuations in the environment of the island might be the result of global warming and it may be the effect of the tsunami in 2004 (Nair et al 2020). Mangrove ecosystems are the treasurable pool of aquatic fauna and flora (Deng et al 2021) and provide ideal breeding and feeding grounds for a wide range of organisms and also they can provide natural defenses against natural calamities and can develop specific arrangements for flood protection and control coastal erosion (Joseph et al 2019). Mangroves are generally recognized as important ecosystems that offer a variety of economic as well as ecological benefits to adjacent communities (Goldberg et al 2020). Globally, mangroves have been seriously affected by natural as well as anthropogenic degradation (Kolli et al 2022). Zooplankton comprises suspended fauna in water-bodies having limited locomotion and is the key components of the food web of aquatic ecosystems (Krztoń and Kosiba 2020) and have strong relations with their environment throughout the lifespan and they reflect quick variations in their populations according to disturbance (Malik et al 2020). These groups are the frequently used indicator fauna for the monitoring of coastal ecosystems due to their various characteristic community structures (Stankovic et al 2014). Disappointingly, aquatic ecosystems are extremely affected through various types of point-source pollutants (Dani et al 2020). Considerable work on zooplankton in the Indian coast has been done from different parts (Biju et al 2016, Thirunavukkarasu et al 2020, Venkataramana et al 2021, Saravanakumar et al 2021). However, the scattered reports on the mangrove environments of Kerala are available (Vidyasagaran and Madhusoodanan 2014, Pillai and Harilal 2018, Surya and Hari 2018). However, the present effort is a first case approach to study the zooplankton abundance in the Munroe Island. The present study aimed to assess the zooplankton abundance during the monsoon period, and also to investigate the influence of water quality on zooplankton abundance.

MATERIAL AND METHODS

Study area and sampling framework: The Munroe Island is a backwater island village situated in the southern part of

Kerala. The Munroe Island lies between 8.9952° N, 76.6105° E and encompasses an area of 13.4 sq. km. The Island is named in honor of John Munroe, former Resident Colonel of the princely state of Travancore. Munroe Island is a tourist destination of Kerala and also this area is characterized with the presence of different types of mangroves. The Island is primarily used for fishing, recreational and aquaculture activities. Currently, Munroe Island is under the threats of continuous flooding and soil erosion. Location map of sampling sites is depicted in (Fig. 1). General characteristics of the sampling sites are depicted in (Table 1).

Environmental variables: The water samples were taken in 1-liter bottles from the ten sites (Fig. 1) of the Munroe Island at a depth of 15-30 cm from the surface during the monsoon season (June to September), 2021. In this study, 14 environmental variables (temperature, turbidity, pH, conductivity, TDS, dissolved oxygen, BOD, COD, hardness, alkalinity, salinity, nitrate, phosphate and silicate) of water were selected. The analytical experimental procedures followed for the analysis of the environmental variables followed APHA (2012).

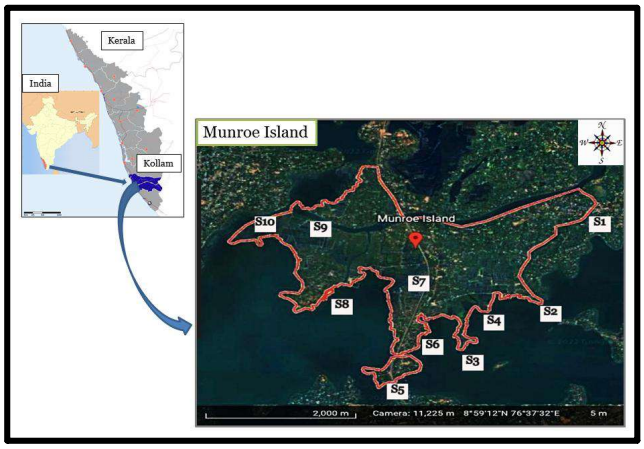


Fig. 1. Location map of study area in Munroe Island, Kerala

Response variables: Zooplankton samples were collected nocturnally at ten sites in the Munroe Island and was collected before dawn from surface waters using a Working Party (WP) net (mesh size 200 µm, mouth area 0.6 m^2) fitted with a flow meter to estimate the volume of water filtered. The net was hauled for 10 minutes at the surface using a small boat at a speed of approximately 2 knots (Fraser 1966). Samples were preserved in 5% formaldehyde. In the laboratory, zooplankton samples were identified by using standard identification procedures (Santhanam et al 2018). Abundance data were expressed as number per cubic meter (No /m^3).

Statistical analysis: Pearson correlation (r) was applied to examine the association between various environmental variables (Gacesa et al 2022). The canonical correspondence analysis was applied to detect the relationship between the environmental variables and response variables (Andronicean et al 2020). The statistical software PAST (Version 4.04) was used for the present investigation.

RESULTS AND DISCUSSION

Environmental variables: During the study period, the water temperature was in the range of 21.20 - 28.45 °C in the study period. The pH and dissolved oxygen in the range of 6.90 - 7.53 and 5.64 - 7.40 mg/l respectively (Table 2). Dissolved oxygen is an important parameter as it can directly indicate the ability of an aquatic system for the sustenance of life (Li et al 2017). The highest dissolved oxygen level at S_1 was due to the photosynthetic activity of aquatic plants and significant turbulence in this area. Reduction in dissolved oxygen could be due to the presence of contaminants that affect the water quality extensively (Zhi et al 2021). The biological oxygen demand (BOD) was lowest at station S_1 (0.17 mg/l) and highest at station S_6 (0.87 mg/l) and chemical oxygen demand (COD) was in the range 9 - 19 mg/l (Table 3).

Table 1. Details of the sampling stations

Sites	Site code	Anthropogenic interferences	Latitude	Longitude
Villimangalam	S_1	Fishing, boating, bridge construction & resorts.	9.0002°	76.6187°
Nenmeny	S_2	Fishing, boating,& resorts	8.9869°	76.6225°
Palliyanthuruthu	S_3	Fishing,& boating.	8.9823°	76.6215°
Neetumthuruthu	S_4	Fishing, &boating.	8.9768°	76.6184°
Pezhumthuruthu	S_5	Fishing, boating, bridge construction & resorts.	8.9777°	76.6073°
Pattamthuruthu	S_6	Fishing, &boating	8.5849°	76.3625°
Kandramkani	S_7	Fishing, boating, &bridge construction	8.9759°	76.6082°
Peringalam	S_8	Fishing, boating, &bridge construction	8.5912°	76.3615°
Kidapram II	S_9	Fishing, boating, &bridge construction	8.9954°	76.6042°
Kidapram I	S_{10}	Fishing, boating, &bridge construction	8.5956°	76.3619°

BOD and COD were comparatively low because of the dilution due to the monsoonal rainfall. Total hardness was in the range 450 (S_1) - 3550 mg/l (S_7), may be due to the influence of the Ashtamudi estuary or it may found due to various anthropogenic activities (Chithra et al 2022). The total alkalinity ranges between 23 and 61 mg/l and varies based on the fluctuation in the pollution level.

The total alkalinity play significant role in estimating the ability of an aquatic system to neutralize acidic contamination from rainfall or wastewater (Priyadharshini and Abraham 2020). The electrical conductivity was in the range of 397.35 – 2848 µS/cm. Electrical conductivity is suitable to identify the quality of waterbodies, and generally high EC values specifies a high level of contamination (Kur et al 2019). The total dissolved solid (TDS) content of water samples ranged between 230 - 1676.3 mg/l. The recorded values of salinity were between 1.77 and 9.73 ppt. The steady increase in TDS, EC and salinity were due to the saltwater intrusion from Ashtamudi estuary through different interconnected channels (Chithra et al 2022). Nitrate was in the range of 0.185 - 0.644. The quantity and form of nitrogen in the water can strongly related to dissolved oxygen content (Zheng et al 2019). Phosphate concentration in water samples varies from 0.12 -0.21mg/l.

The present concentration of phosphate poses no threat to aquatic life. Silicate concentration ranged between 3.83 and 7.65 mg/l. Dissolved silicate is an important nutrient in brackish water. The major source of dissolved silicate in the present examination may be due to the influx of water from land drainage (Dani et al 2021) and also added by the Kallada River through several channels.

Zooplankton abundance: The zooplankton was maximum at S_5 (72745No/m^3) followed by S_6 , S_3 , S_4, and S_8 (Fig. 2). Among the zooplankton communities, copepoda was maximum (32740 No/m^3) and chaetognatha showed minimum (3 No/m^3). Water quality variables such as dissolved oxygen, salinity and temperature play a pivotal role in influencing zooplankton abundance. The higher abundance of copepoda may be due to their quick

Table 2. Water quality parameters of Munroe Island

Stations	Temperature (^{0}C)	Turbidity (NTU)	EC	TDS	pH	DO (mg/l)	Salinity (ppt)
S1	26.25 ± 0.07	7.34 ± 0.12	397.35 ± 1.48	230 ± 0.21	6.90 ± 0.08	7.40 ± 0.71	1.77 ± 0.11
S2	25.55 ± 0.49	7.79 ± 0.34	2030.20 ± 24.75	999.5 ± 1.86	7.30 ± 0.02	6.79 ± 0.14	4.07 ± 0.06
S3	26.45 ± 0.49	6.67 ± 0.49	2051.00 ± 46.67	1184.5 ± 19.84	7.18 ± 0.04	5.64 ± 0.93	6.61 ± 0.16
S4	28.45 ± 0.07	8.10 ± 0.06	2228.50 ± 23.33	1290.6 ± 10.77	7.36 ± 0.07	6.64 ± 0.49	7.17 ± 0.03
S5	24.45 ± 0.49	8.58 ± 0.36	2495.00 ± 1.41	1473.9 ± 38.66	7.20 ± 0.07	6.82 ± 0.18	7.35 ± 0.21
S6	24.30 ± 0.14	9.35± 0.11	2848.00 ± 5.66	1676.3 ± 31.35	7.37 ± 0.11	6.80 ± 0.15	9.73 ± 0.26
S7	24.35 ± 0.35	7.61 ± 0.16	1241.00 ± 16.97	744.6 ± 20.71	7.53 ± 0.09	6.99 ± 0.13	7.63 ± 0.18
S8	27.30 ± 0.28	8.29 ± 0.17	1068.00 ± 25.46	612.15 ± 4.38	7.26 ± 0.07	6.73 ± 0.36	8.71 ± 0.26
S9	21.20 ± 0.14	8.81 ± 0.07	933.55 ± 19.30	537.07 ± 4.99	7.46 ± 0.07	6.94 ± 0.49	3.32 ± 0.30
S10	24.65 ± 0.35	7.55 ± 0.10	565.30 ± 30.97	320.15 ± 7.03	6.95 ± 0.06	6.62 ± 0.46	3.10 ± 0.09

Table 3. Water quality parameters of Munroe Island

Stations	BOD (mg/l)	COD (mg/l)	Hardness (mg/l)	Alkalinity (mg/l)	NO_3- (mg/l)	PO_4^{3-}(mg/l)	SiO_2 (mg/l)
S1	0.17 ± 0.16	9 ± 1.41	450.00 ± 70.71	23.00 ± 1.41	0.401 ± 0.014	0.22 ± 0.05	7.21 ± 0.34
S2	0.41 ± 0.06	11 ± 1.41	3100.00 ± 141.42	53.00 ± 1.41	0.185 ± 0.005	0.30 ± 0.04	4.63 ± 0.70
S3	0.25 ± 0.40	13 ± 1.41	2350.00 ± 141.42	37.00 ± 1.41	0.644 ± 0.029	0.34 ± 0.10	5.13 ± 0.70
S4	0.78 ± 0.29	15 ± 2.83	3350.00 ± 70.71	47.00 ± 1.41	0.306 ± 0.021	0.29 ± 0.04	4.96 ± 0.36
S5	0.41 ± 0.06	14 ± 1.41	2650.00 ± 70.71	45.00 ± 2.83	0.245± 0.058	0.32 ± 0.04	3.93± 0.32
S6	0.87 ± 0.16	14 ± 2.83	3300.00 ± 141.42	61.00 ± 1.41	0.306 ± 0.021	0.27 ± 0.07	3.83 ± 0.42
S7	0.39 ± 0.09	13 ± 1.41	3550.00 ± 70.71	56.00 ± 2.83	0.385 ± 0.041	0.15 ± 0.01	4.82 ± 1.14
S8	0.45 ± 0.13	19 ± 1.41	1350.00 ± 70.71	34.00 ± 2.83	0.345 ± 0.041	0.22 ±0.02	5.46 ± 0.49
S9	0.67 ± 0.44	13 ±2.83	1425.00± 35.36	29.00 ± 1.41	0.378 ± 0.048	0.29 ± 0.17	5.01 ± 0.29
S10	0.60 ± 0.21	11 ± 1.41	1100.00 ± 141.42	26.00 ± 2.83	0.298 ± 0.032	0.25 ± 0.03	7.65 ± 0.68

reproductive quality, egg production, and the ability to tolerate environmental variations (Brennan et al 2022).

Canonical correspondence analysis: The relationships between zooplankton abundance and water quality variables were explored by CCA ordination (Turhan and Gokçe 2022). The first canonical axis accounted for 72.65% (Eigenvalue, 0.031) and the second for 21.1% (Eigenvalue, 0.009) of the variance. The CCA model confirmed that water quality variables such as DO, NO_3-, PO_4^{3-}, SiO_2, positively correlated to zooplankton groups such as Amphipoda and Decapoda in the first axis. The conductivity, TDS, pH, hardness, alkalinity, salinity, and BOD showed negative correlation with zooplankton groups such as chaetognatha, copepoda (Eigenvalue, -0.55), and luciferidae, in the first axis (Fig. 4). In the second canonical axis, environmental variables, temperature, turbidity, BOD (Eigenvalue, 0.76), COD, salinity (Eigenvalue, 2.63), PO_4^{3-} (Eigenvalue, 1.12), and SiO_2 (Eigenvalue, 0.62), and zooplankton group copepoda were positively correlated whereas Conductivity, TDS, pH, hardness, alkalinity, DO, and NO_3- (Eigenvalue, -0.99) and zooplankton groups such as chaetognatha, amphipoda, decapoda, and luciferidae in the second axis (Fig. 4). All the aforementioned hydrographical variables revealed a strong relation to zooplankton abundance.

The ordination of the response variables by CCA showed that the patterns were significantly associated to the spatial variation observed in the Munroe Island and indicated clear separation of zooplankton groups based on their environmental requirements. Zooplankton groups such as amphipoda and decapoda showed the peak of its abundance where dissolved oxygen level was high (Granata et al 2020, Purushothaman et al 2021). The CCA also revealed the abundance of the remaining groups in habitats with high conductivity, TDS, alkalinity, hardness and salinity concentration, implying were able to tolerate habitats with such environmental conditions (Furst et al 2019, El-Metwally et al 2022). The obtained CCA results are very much similar to the indication of correlation coefficient results (Table 5). This analysis discloses the influence of water quality variations in Munroe Island.

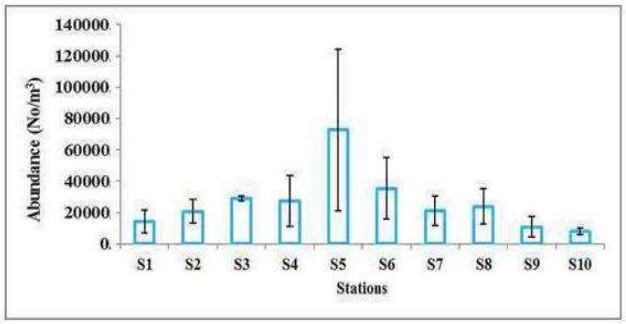
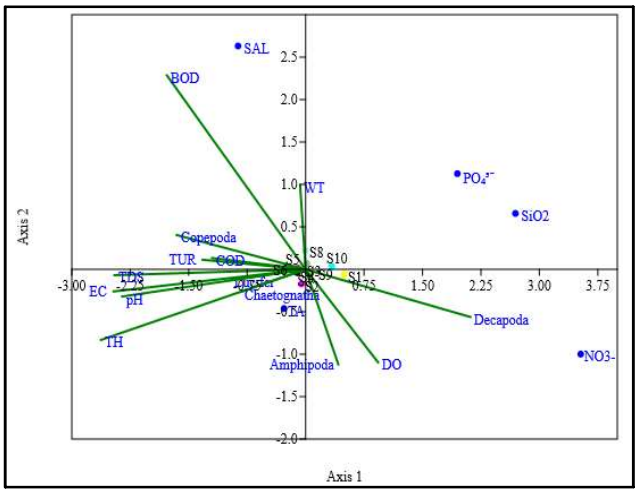


Fig. 2. Zooplankton abundance (No/m^3) in study sites of Munroe Island



Abbreviations: Z1: Chaetognatha, Z2: Amphipoda, Z3: Decapoda, Z4: Copepoda, Z5: Luciferidae, WT: water temperature, DO: dissolved oxygen, EC: electrical conductivity, TDS: total dissolved solids, TH: total hardness, TA: total alkalinity, SAL: salinity, BOD; biological oxygen demand, and COD: chemical oxygen demand

Fig. 3. Canonical correspondence analysis triplot with zooplankton community and environmental variables

Table 4. Canonical correspondence analysis

Variables	Axis 1	Axis 2
Chaetognatha	-0.276	-0.088
Copepoda	-0.551	0.135
Amphipoda	0.142	-0.373
Decapoda	0.705	-0.187
Luciferidae	-0.321	-0.041
Temperature	-0.024	0.331
Turbidity	-0.442	0.038
Conductivity	-0.821	-0.087
TDS	-0.817	-0.023
pH	-0.785	-0.107
Dissolved oxygen	0.312	-0.365
BOD	-0.593	0.762
COD	-0.412	0.044
Total hardness	-0.876	-0.277
Total alkalinity	-0.277	-0.462
Salinity	-0.867	2.631
NO_3-	3.532	-0.999
PO_4^{3-}	1.948	1.128
SiO_2	2.693	0.659

Table 5. Pearson correlation coefficient matrix analyzedvariables of Munroe Island ($p < 0.05$)

Variables	Z1	Z2	Z3	Z4	Z5	WT	TUR	EC	TDS	pH	DO	BOD	COD	TH	TA	SAL	NO_3-	PO_4^{3-}	SiO_2
Z1	1																		
Z2	0.14	1																	
Z3	0.62	0.23	1																
Z4	0.49	0.36	0.69	1															
Z5	0.05	0.02	0.91	0.55	1														
WT	0.75	0.83	0.29	0.94	0.85	1													
TUR	0.21	0.35	0.82	0.19	0.79	0.24	1												
EC	0.24	0.41	0.56	0.09	0.14	0.71	0.28	1											
TDS	0.29	0.46	0.39	0.10	0.16	0.73	0.25	0.30	1										
pH	0.94	0.77	0.96	0.04	0.82	0.43	0.19	0.24	0.22	1									
DO	-0.07	0.62	0.70	-0.34	-0.45	-0.46	-0.27	-0.89	-0.79	-0.63	1								
BOD	0.85	0.32	0.45	0.03	0.79	0.43	0.23	0.41	0.35	0.19	-0.84	1							
COD	0.09	0.98	0.97	0.25	0.49	0.60	0.01	0.28	0.25	0.19	-0.95	0.35	1						
TH	0.50	0.23	0.63	0.21	0.65	0.81	0.53	0.31	0.41	0.03	-0.58	0.55	0.31	1					
TA	0.72	0.24	0.58	0.32	0.70	0.93	0.30	0.41	0.31	0.04	-0.88	0.55	0.30	0.40	1				
SAL	0.84	0.09	0.11	0.15	0.73	0.51	0.25	0.04	0.32	0.11	-0.43	0.40	0.31	0.05	0.03	1			
NO_3-	0.56	0.90	0.64	0.15	0.74	0.60	0.19	0.39	0.38	0.06	0.26	0.12	0.40	0.13	0.21	0.10	1		
PO_4^{3-}	0.89	0.47	0.64	0.33	0.80	0.16	0.16	0.23	0.21	0.40	0.49	0.92	0.32	0.04	0.05	0.36	0.49	1	
SiO_2	0.30	0.06	0.78	0.02	0.23	0.66	0.11	0.40	0.30	0.41	0.59	0.20	0.37	0.40	0.40	0.02	0.27	0.02	1

Values in bold are different from 0 with a significance level alpha=0.05

CONCLUSION

The water quality variables influencing zooplankton abundance fluctuated markedly with the spatial scales in Munroe Island of Kerala which were affected by various human interference. The higher concentrations of conductivity, TDS, hardness, alkalinity and salinity were considerably contributed by the Ashtamudi estuary. Results from CCA indicated, the clear separation of zooplankton groups based on the changes occurred in the water quality in spatial scale. This first case approach provides new insights for the conservation policies of Munroe Island under various anthropogenic influences.

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