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EVALUATING SURFACE WATER QUALITY VARIATION IN PHU MY SPECIES-HABITAT CONSERVATION IN KIEN GIANG PROVINCE, VIETNAM

***Nguyen Thanh Giao*[1], *Huynh Thi Hong Nhien*[2]**

[1] ORCID: 0000-0001-5916-4710
[2] ORCID: 0000-0003-4902-3986
[1,2] College of Environment and Natural Resources
Can Tho University, Xuan Khanh Ward, Ninh Kieu District, Can Tho City, Vietnam

Key words: acid sulfate soil, conservation area, Phu My, Vietnam, water quality.

Abstract

The study aimed to assess the variation of surface water quality in the Phu My Species-Habitat conservation area (conservation area) in 2019–2022. Fourteen water quality indicators including pH, electrical conductivity (EC), turbidity (Turb), salinity (Sal), total suspended solids (TSS), dissolved oxygen (DO), biochemical oxygen demand (BOD), oxygen demand chemical (COD), ammonium (NH_4^+-N), nitrate (NO_3^--N), orthophosphate (PO_4^{3-}-P), total phosphorus (TP), iron (Fe^{2+}) and aluminum (Al^{3+}) were analyzed. Correlation Pearson and cluster analysis (CA) were performed to find the correlation between surface water environmental parameters and locations with similar physical and chemical characteristics of water. The results showed that the surface water in the Phu My conservation area was acidic, with low pH and high concentrations of Fe^{2+} and Al^{3+}. The amounts of organic substances (except COD) and nutrients (NH_4^+-N, NO_3^--N, and PO_4^{3-}-P) in the study area were relatively low. Surface water quality is being well managed to develop key species in the Phu My Species-Habitat conservation area, Lepironia and Eleocharis species. The correlation analysis result indicates that organic matter and nutrients have a positive linear correlation, having the same origin formed from the degradation of organic matter from dying flora and fauna and agricultural activities in the study area. The CA analysis results show that the monitoring system was relatively suitable and could be applied in the future.

Introduction

In Vietnam, wetlands occupy about 12 million hectares, which are irreplaceable in balancing the ecosystem, nutrition, and habitat for many plant and animal species. Wetlands might flood frequently or change sig-

Address: Nguyen Thanh Giao, Can Tho University, 3-2 Street, Xuan Khanh Ward, Ninh Kieu District, Can Tho City, Vietnam, e-mail: ntgiao@ctu.edu.vn

nificantly in water levels within the area (seasonal wetlands). These areas are strictly managed and protected based on different wetland policies, such as Decree No. 66/2019/ND-CP on the preservation and sustainable use of wetlands (Vietnam Government 2019). However, these lands face various challenges, such as environmental pollution, climate change, or shrinking areas due to encroachment. According to a previous report by TRAN et al. (2019), Giang Thanh district, where Phu My is located, will be flooded by up to 99% when the sea level rises by 100 cm.

Phu My Species-Habitat Conservation Area is located at 10º26'41.3" North latitude and 104º36'17.3" East longitude, established in March 2016 to conserve biodiversity in the Long Xuyen Quadrangle, in which priority is given to conservation of the remaining Lepironia grassland in the Vietnamese Mekong Delta. The total land area of the conservation area is 957.87 ha, with three functional areas, including the administrative service area, the ecological restoration area, and the strict protection area. According to NI (2018), the composition of flora and fauna in the reserve is quite diverse, with more than 456 species recorded, including 47 species of higher plants, 126 species of birds, 30 species of fish, 13 species of reptile and amphibians, 72 species of algae, 67 species of zooplankton, 8 species of benthic animals, 39 species of spiders and 54 species of aquatic insects. However, the number of species in the conservation area tended to decrease over time (GIAO 2021). More specifically, the main food source (Eleocharis species) of crane (*Grus antigone sharpii*) – an endangered species listed in the Red Book of Vietnam and the world, is shrinking. One of the most important reasons for declining biodiversity is water environmental quality in the Phu My Species-Habitat conservation area. This has also been evaluated in many previous studies at various water bodies on the impact of water quality on ecosystems and aquatic organisms (SUMANDIARSA et al. 2023, ONAH 2023). Therefore, water monitoring needs to be conducted regularly and continuously to assess environmental quality promptly, as well as warn of unusual signs affecting the ecosystem's development in the conservation area's water bodies. Nevertheless, there has been no research to evaluate the change in water quality over the years in the conservation area since its establishment. Hence, the present research was carried out to evaluate the water quality changes in the Phu My Species-Habitat conservation area from 2019 to 2022 to provide scientific information for the management and sustainable development of the reserve.

Materials and Methods

Water sampling and analysis

A total of eight surface water samples were collected at locations belonging to the different habitats from 2019 to 2022. Since the conservation area was established management policy based on three functional zones in 2018, the environmental monitoring has been carried out annually until the present. The habitats that have been selected for monitoring include the infield canal, *Lepironia articulata*, Eleocharis, *Melaleuca cajuputi* – Eleocharis, *Melaleuca cajuputi* – *Lepironia articulata*, *Lepironia articulata* – Eleocharis, Peripheral canal (Figure 1). In order to evaluate the characteristics of water quality, water samples were analyzed with fourteen parameters, including pH, electrical conductivity (EC), turbidity (Turb), salinity (Sal), total suspended solids (TSS), dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD), ammonium (NH_4^+-N), nitrate (NO_3^--N), orthophosphate (PO_4^{3-}-P), total phosphorus (TP), iron (Fe^{2+}) and aluminum (Al^{3+}). The pH, EC, salinity, and DO parameters were measured directly in the field. Turbidity, TSS, BOD, COD, NH_4^+-N, NO_3^--N, PO_4^{3-}-P, TP, Fe^{2+}, and Al^{3+} were collected, stored, and transported properly and analyzed using standard methods (APHA 1998).

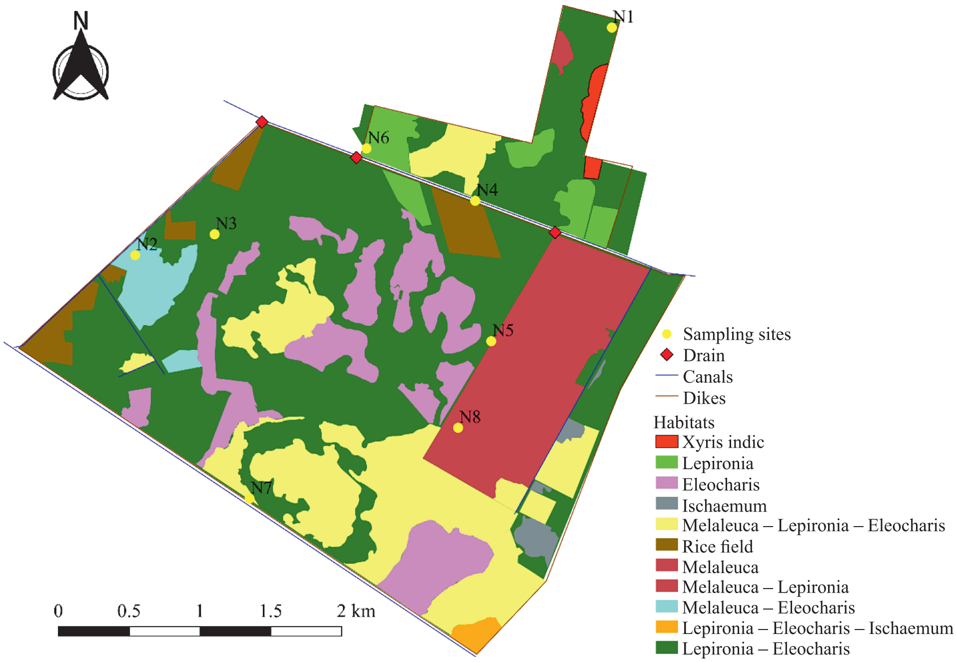


Fig. 1. Map of the sampling locations in the conservation area

Data analysis

The study applied the One-way ANOVA analysis method by using IBM SPSS Statistics for Windows software (version 20.0 IBM Corp., Armonk, NY, USA) to evaluate the statistically significant differences in surface water quality in each water body over the monitoring years 2019– 2022. A Post hoc (Duncan) test was used to show the difference in surface water quality at a 95% significance level ($p < 0.05$). Surface water quality in the study area was compared with national technical regulations on surface water quality (QCVN 08-MT:2015/BTNMT) (Ministry of Natural Resources and Environment in Vietnam 2015). Multivariate statistics such as Pearson correlation analysis and cluster analysis (CA) were performed to find the correlation between environmental indicators affecting surface water quality from 2019 to 2022 and determine suitable monitoring locations.

Results and Discussion

Variation of surface water quality in the reserve during 2019–2022

pH. The analysis found that the pH value in the water bodies of the conservation area fluctuated relatively stable between 2019 and 2022 (Figure 2). The average pH changes in water bodies fluctuated in the range of 3.33 ±0.55–4.68 ±2.58, and the lowest and highest pH were detected in the in-field canals (2020) and rice fields (in 2021), respectively. pH values in the habitats and in-field canals fluctuated between 2.69–4.05 and 2.37–7, while these values in the rice fields and peripheral canals were higher, with about 3.18–8.54 and 3.41–5.52, respectively. pH values gradually increased during the first three years and decreased slightly in 2022 (Figure 2). It can be seen that the pH is acidic; this could be explained by the fact that the soil in this area is acidic soil, which could be suitable for the development of seasonally inundated grassland. Moreover, the previous study of Ni (2018) only has a few species of black fish that are small and capable of living in conditions of heavy alum, low water level, and low nutrition, such as *Anabas testudineus* and other exotic species. pH values were lower than the allowable limit for surface water quality for conserving aquatic plants and animals in column A1 of QCVN 08-MT:2015/ BTNMT (6–8.5). However, this condition was suitable for the growth of Lepironia and Eleocharis, which are key species in the conversation area. Compared with the study of Du et al. (2019), the pH value in water in

U Minh Ha – Ca Mau National Park (5.78 ±0.03–5.83 ±0.78) was also lower than the allowable limit for surface water quality used to conserve aquatic plants and animals. However, the pH in this area is higher than that in the current study area. Whereas the average pH value in the water at Mua Xuan Agriculture Center (Hau Giang province) was higher than in this present study. It creates favorable conditions for aquatic organisms to grow, fluctuating in the range of 6.2 ±0.05–6.7 ±0.01 (Dan et al. 2017). pH profoundly affects the solubility of metals (at low pH), alkalinity, and hardness of water, and aquatic organisms are also affected by pH because of most metabolic activities (Wakawa et al. 2010).

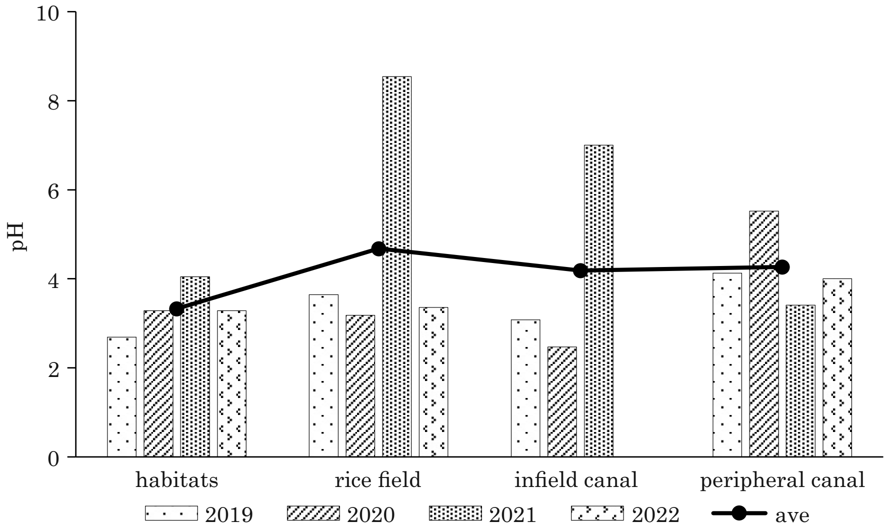


Fig. 2. Variation of pH in the period of 2019–2022 in the conservation area

Electrical conductivity and salinity. Electrical conductivity (EC) is one of the most important water quality parameters for predicting the salinity and mineralization of water (Ahmadianfar et al. 2020). The results show that EC values and salinity in water in the study area tended to fluctuate similarly from 2019 to 2022, which tended to decrease gradually from 2019 to 2021 and, after that, increased in 2022 (Figure 3). The average value of EC and salinity in water in the water bodies fluctuated between 0.24 ±0.11–0.65 ±0.16 mS/cm and 0.10 ±0.07–0.34 ±0.07‰. The lowest and highest EC values were detected at peripheral canals (in 2020) and the habitats in the reserve (in 2019). EC values in water in habitats, rice fields, in-field canals, and peripheral canals in the period 2019–2022 fluctuated from 0.48–0.85 mS/cm,0.16–0.46 mS/cm, 0.21–0.91 mS/cm and

0.11–0.37 mS/cm, respectively. The salinity in each water body in the period of 2019–2022 ranged from 0.27–0.40‰ (habitats), 0.07–0.20‰ (rice fields), 0.15–0.46‰ (infield canals) and 0.04–0.19‰ (peripheral canals). As a result, it was found that the EC value and the lowest salinity in the peripheral canal could be due to the concentration of ions in the water being diluted in the surrounding canals, leading to a low EC value. The habitats in the reserve have high EC values and salinity because they contain a significant amount of dissolved ions. The difference in EC values and salinity in the study area is mainly due to the presence of dissolved ions present in the acid sulfate soil (GIAO et al. 2020).

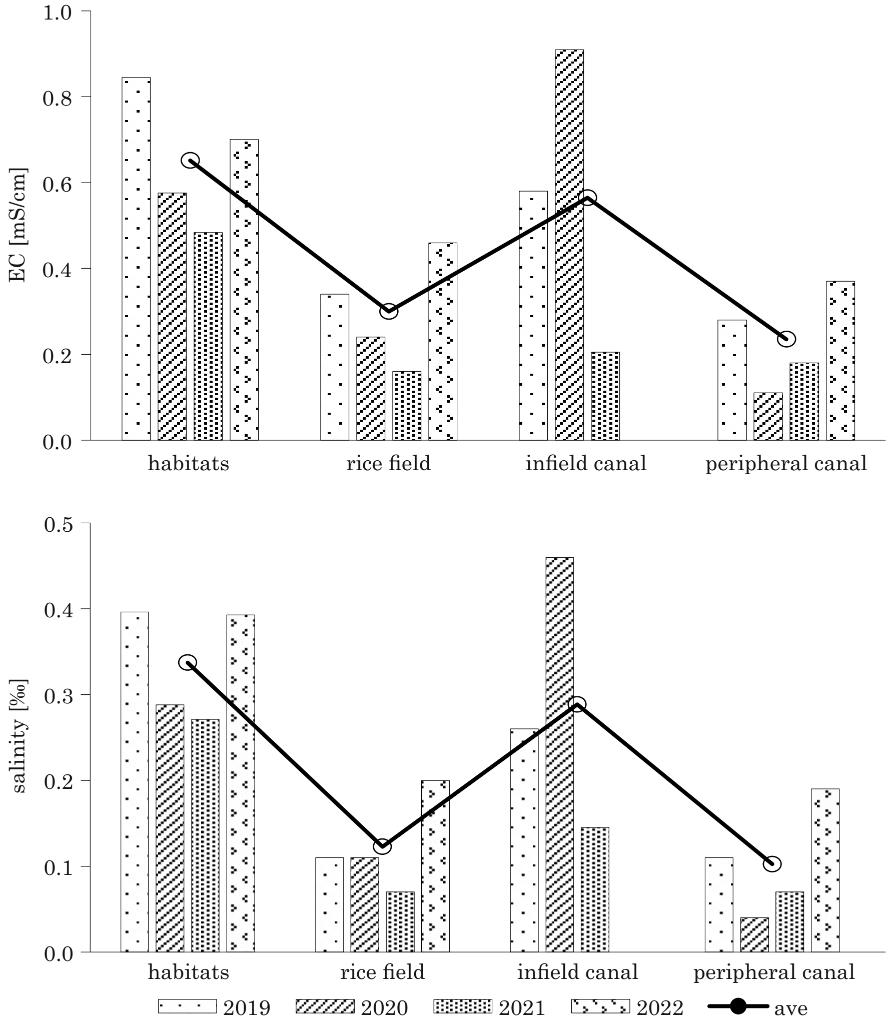


Fig. 3. Variation of EC and Salinity in the period of 2019–2022 in the conservation area

Turbidity and total suspended solids. Turbidity is a measure of the ability to absorb light, reflecting the degree of transparency or opacity of water, and is influenced by the amount of suspended matter present in the water column (Catianis et al. 2020). The average water turbidity in the studied bodies in 2019–2022 varied from 5.15 ±4.28–77.92 ±88.87 NTU (Figure 4). The results illustrate that the habitat area has the lowest turbidity in the water because it is less affected by waste sources. In addition, water environments with low pH and high Al^{3+} are hydrolyzed into $Al(OH)_3$, absorbing suspended solids in the water and dragging them to the bottom. Meanwhile, the peripheral canal area has the highest turbidity in the water, which may be affected by boat activities and other waste sources in the study area. The results also show that the turbidity in the water tended to decrease in 2022 compared to 2021. Compared with the studied water bodies at Lung Ngoc Hoang Nature Reserve (20.8–72.5 NTU), the turbidity in the water in the present study tended to be higher. High turbidity could be attributed to the high TSS concentration in the water (Hong and Giao 2021). According to Catianis et al. (2020), high turbidity, i.e., the presence of organic pollution, other wastes, or runoff with high suspended matter content, reduces water visibility and affects aquatic biodiversity. Aquatic animals are only indirectly affected by the processes caused by high turbidity, such as decreased dissolved oxygen and the penetration of sunlight into the water (Catianis et al. 2020).

The study results showed that the average concentration of TSS in the studied water bodies from 2019–2022 ranged from 10.83 ±8.50–22.80 ±30.84 mg/L. It was found that there was no difference between TSS concentrations in water bodies during the monitoring period ($p > 0.05$). However, there was a statistically significant difference in the same water body over the years of monitoring ($p < 0.05$). TSS concentrations in aquatic habitats, rice fields, infield canals, and peripheral canals between 2019 and 2022 varied from 3.50–22.73 mg/L, 0–25.11 mg/L, 0–57.89 mg/L, and 10.3–25.53 mg/L, respectively. TSS in water tended to decrease gradually from 2021 to the present study time, similar to the previous study of Luu et al. (2020). The values of TSS in infield canals exceeded the allowable limit of QCVN 08-MT:2015/BTNMT, column A1 in 2021 (Monre 2015). Meanwhile, the habitat area has the lowest TSS content, where there is less human influence and poor flow. Comparing the current water bodies with water bodies that are heavily affected by boat activities, domestic waste, cultivation, animal husbandry, and industry, the TSS content in the water in the Phu My protected area – habitat was much smaller (Wakawa et al. 2010, Giao et al. 2020, Ky et al. 2020). High TSS content in water reduces the ability to transmit light into the water, thereby affecting the photosynthesis process of aquatic plants, causing depletion of dissolved oxygen in water and affecting aquatic life (HONG and GIAO 2021).

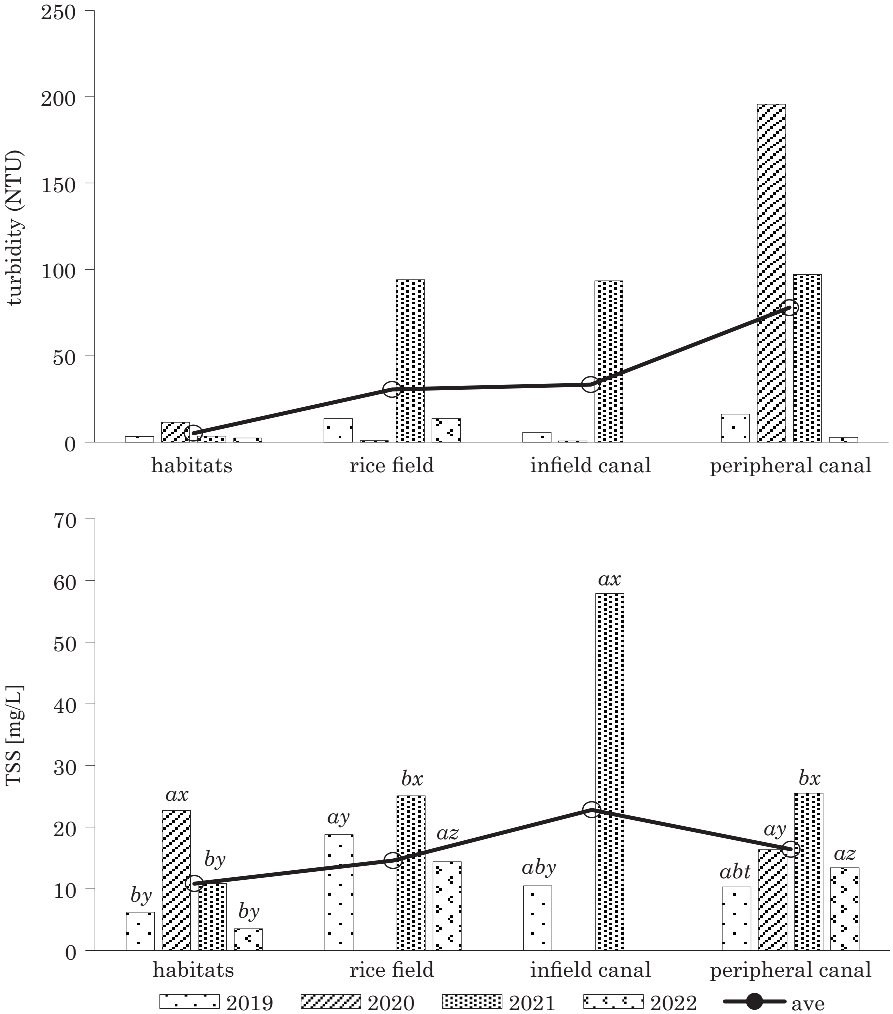


Fig. 4. Variation of turbidity and TSS in the period of 2019–2022 in the conservation area
Explanations: *a, b* are statistically significant differences between water bodies in the same monitoring year *(p* < 0.05*) and x, y, z, t* are significantly different between monitoring years in the water bodies *(p* < 0.05*)*

Dissolved oxygen (DO), biochemical oxygen demand (BOD), and chemical oxygen demand (COD). The dissolved oxygen (DO) of natural water depends on temperature, surface turbulence, surface area exposed to the atmosphere, atmospheric pressure and the amount of oxygen in the surrounding air (NDUKA et al. 2008). DO concentrations in water bodies of the conservation area in 2019–2022 ranged from 3.74 ±1.14–5.71 ±1.11 mg/L (Figure 5).

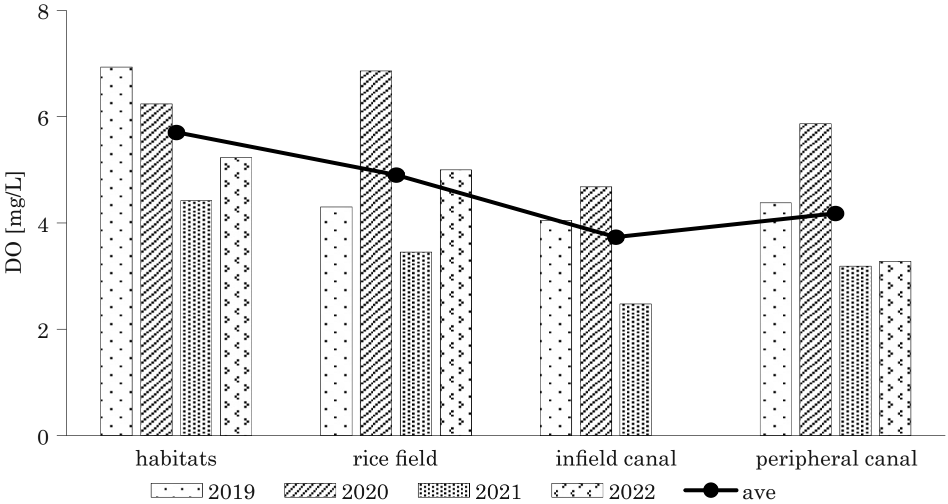


Fig. 5 Variation of DO in the period of 2019–2022 in the conservation area

DO in the infield canal (2021) and habitats (2019) were lowest and highest, with 2.48–4.68 mg/L and 4.42–6.94 mg/L, respectively. The data on rice fields and peripheral canals were 3.54–6.86 mg/L and 3.19–5.87 mg/L, in their respective order. DO tended to decrease gradually between 2019 and 2021 and increase in 2022. However, the DO content in the water in the study area does not meet the limit value of column A1 of QCVN 08-MT:2015/BTNMT, which is unsuitable for the water supply and conservation of aquatic plants and animals. The flow is poor at the main monitoring sites, and the water exchange capacity is limited, leading to low oxygen in the water. In some other water bodies, the DO content is low in water due to several reasons, such as highly suspended solids, receiving a large amount of wastewater with only partial or no treatment, and the decomposition of organic matter (WAKAWA et al. 2010, HA et al. 2016, TRUC et al. 2019). According to CATIANIS et al. (2020), DO concentrations below 5 mg/L can adversely affect biotic communities' function and survival, and below 2 mg/L can lead to fish death. According to NDUKA et al. (2008), DO concentration of 3 mg/L can interfere with fish populations through slow hatching of eggs and reduction in embryo size and viability.

The average BOD and COD concentrations in the water in the study area during the period of 2019–2022 ranged from 1.99 ±0.97–3.43 ±1.95 mg/L and 18.77 ±18.33–24.59 ±30.62 mg/L (Figure 6).

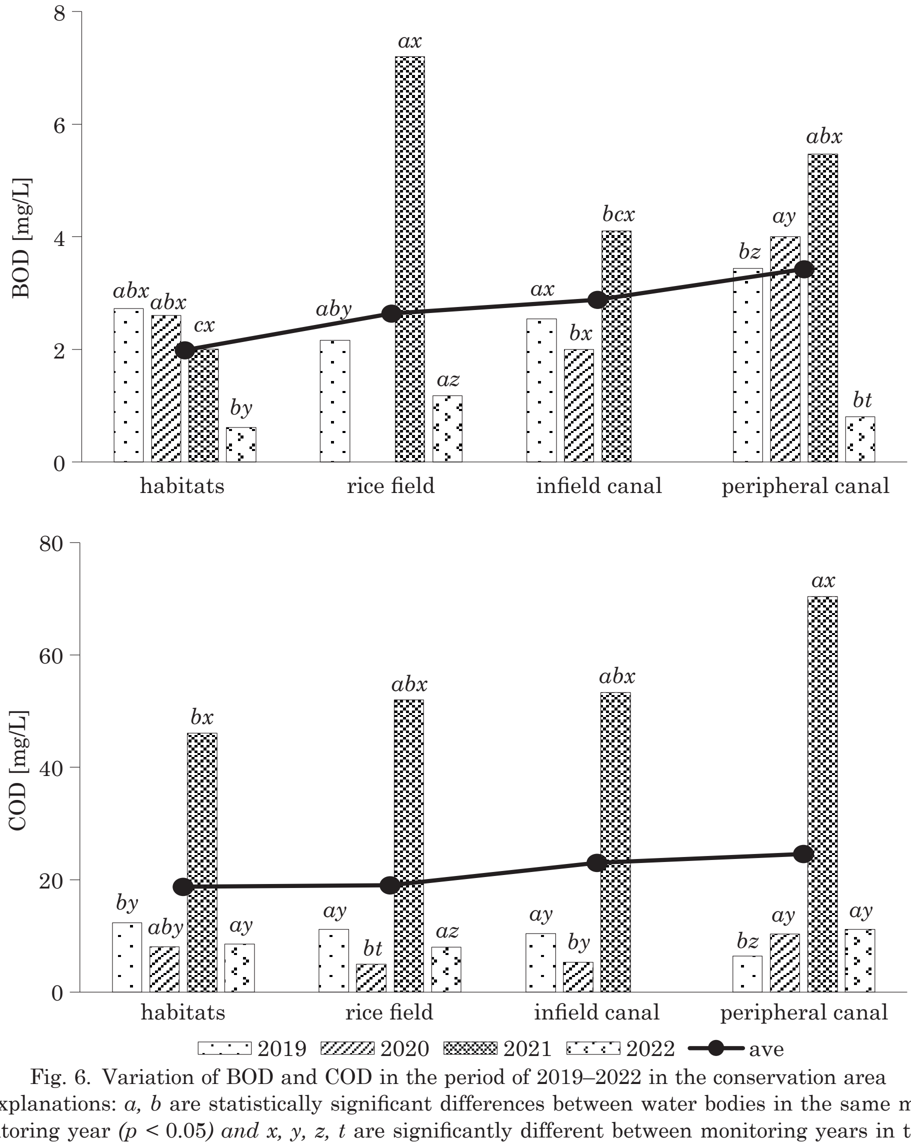
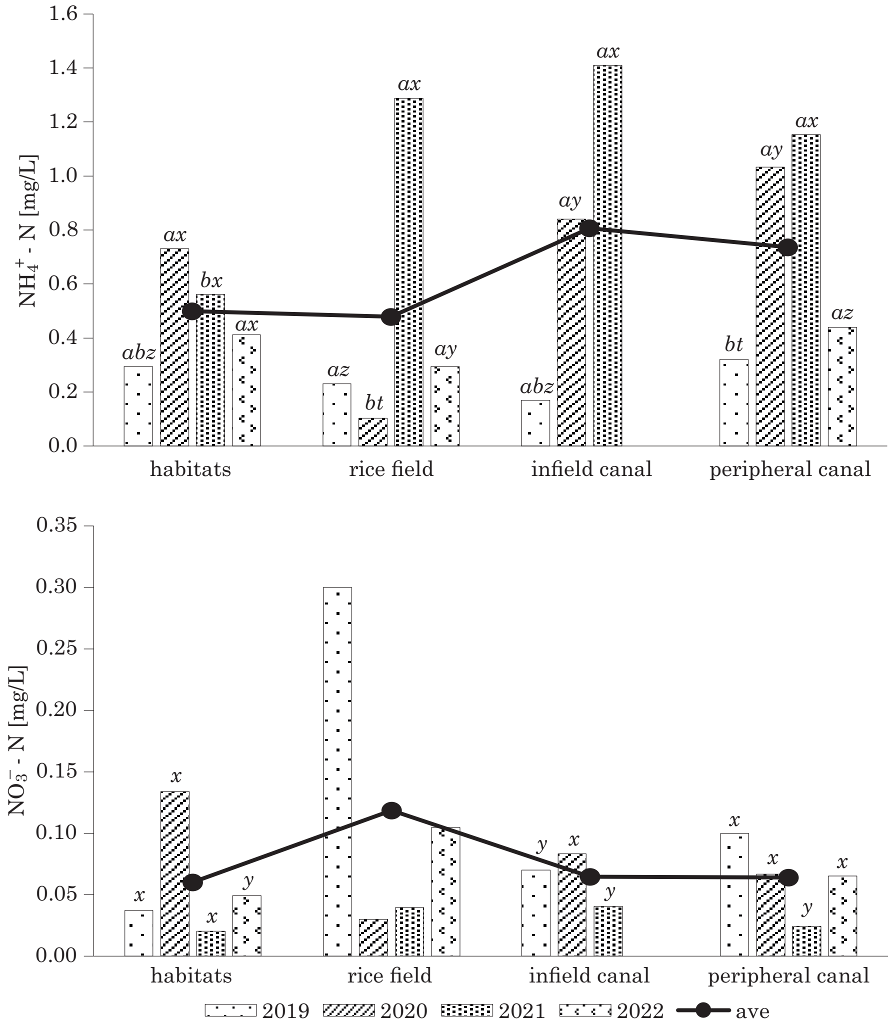


Fig. 6. Variation of BOD and COD in the period of 2019–2022 in the conservation area
Explanations: *a, b* are statistically significant differences between water bodies in the same monitoring year *($p < 0.05$) and x, y, z, t* are significantly different between monitoring years in the water bodies *($p < 0.05$)*

Statistical analysis found that the BOD and COD concentrations between water bodies in the same year were not statistically significant ($p > 0.05$). The evolution of BOD content in each habitat, rice field, infield canal, and peripheral canal in the period of 2019–2022 fluctuated in the range of 0.61–2.73 mg/L, 0–7.20 mg/L, 2–4.10 mg/L, and 0.80–5.47 mg/L, respectively. For COD content, it fluctuated from 8.07–46.11 mg/L, 5–52.02 mg/L, 5.33–53.33 mg/L, and 6.40–70.41 mg/L, respectively, for habitats, rice fields, and infield canals and external canals. This result shows that the aquatic habitats have the lowest BOD and COD concentrations among the four surveyed water bodies and are suitable for conserving aquatic plants and animals. Statistical analysis results show that the organic matter content in the rice fields and the peripheral canals fluctuated significantly over the years ($p < 0.05$). Besides, the results also show that the BOD concentration decreased at present compared to the previous year (in 2021). At the same time, the COD content tended to fall in 2019–2020 and increase sharply, exceeding the allowable limit of QCVN 08-MT:2015/BTNMT, Column A1 in 2021 and decreasing in 2022. In general, the concentration of BOD in the conservation area is still within the allowable limit of QCVN 08-MT:2015/BTNMT, Column A1. Nevertheless, the COD concentration in the water bodies of the study area was relatively high and exceeded the permissible limit. From the above analysis, it is proved that the aquatic habitats in the NR have the best environmental quality in terms of organic pollutants, with both BOD and COD content lower than the remaining water bodies.

Nutrients (NH_4^+-N, NO_3^--N, PO_4^{3-}-P, TN). The concentration of ammonium in water in water bodies ranges from 0.48 ±0.55–0.81±0.65 mg/L from 2019 to 2022, reaching the highest value in the infield canal water bodies (in 2021) and the lowest in the rice fields (in 2020). The content of NH_4^+-N in each habitat, rice field, infield, and peripheral canals with values of 0.29–0.73 mg/L, 0.10–1.29 mg/L, 0.17–1.41 mg/L and 0.17–1.41 mg/L, 0.32–1.15 mg/L, respectively (Figure 7). NH_4^+-N content increased gradually from 2019–2021, followed by a decrease in 2022. However, the average NH_4^+-N concentration in water bodies has exceeded the allowable limit of QCVN 08-MT:2015/BTNMT (column A1) for aquatic flora and fauna conservation and domestic water supply. Based on the statistical analysis results, there was no statistically significant difference in the concentration of NH_4^+-N in water bodies in the same year ($p > 0.05$). In contrast, the fluctuations over the surveyed period in each water body were found to be a statistical difference at a 95% significance level ($p > 0.05$). According to Boyd and Green (2002) classified the level of eutrophication in freshwater systems for nitrogen concentration from 0.18–0.43 mg/L. Thereby, there was a sign of eutrophication in the study area. The nitrate content in water in the conservation is very low, still within the allowable limit of QCVN 08-MT: 2015/BTNMT. The concentration of NO_3^--N in water bodies fluctuated from 0.06 ±0.03–0.12 ±0.13 mg/L in 2019–2022. Statistical analysis showed that the NO_3^--N concentration in the same water body was not a statistically significant difference (p > 0.05). NO_3^--N has gradually increased from 2021 to the current study time (in 2022).



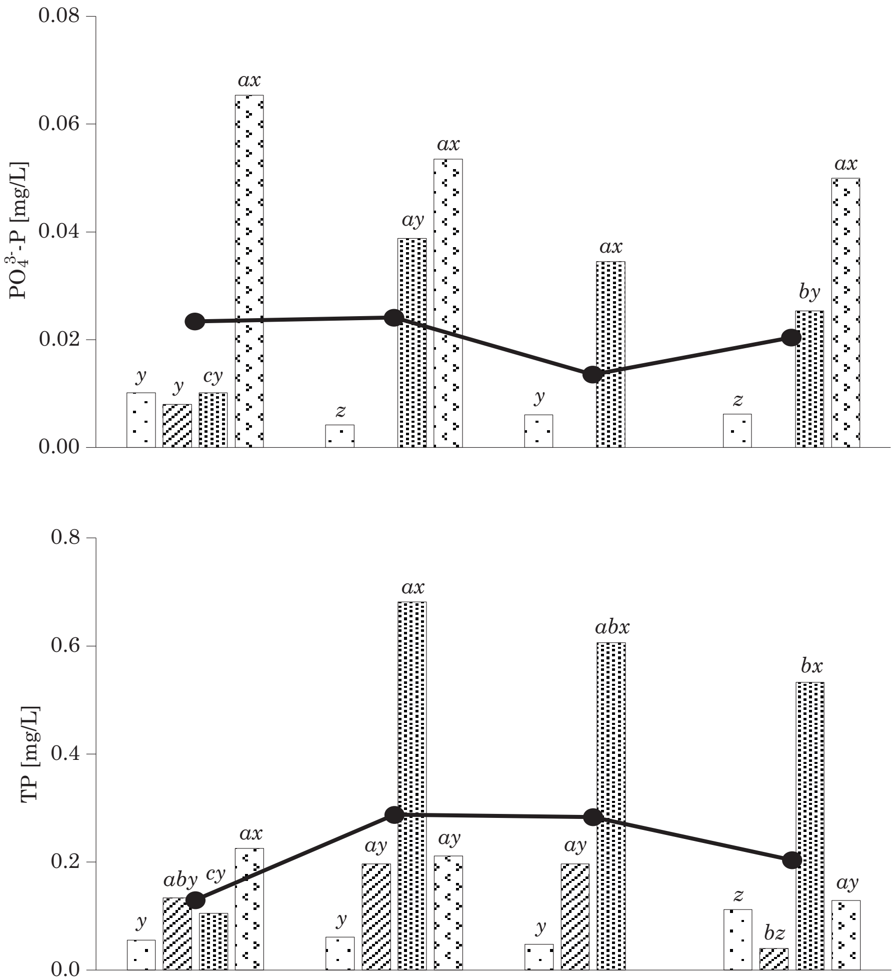


Fig. 7. Variation of nutrients in the period of 2019–2022 in the conservation area
Explanations: *a, b* are statistically significant differences between water bodies in the same monitoring year *($p < 0.05$) and x, y, z, t* are significantly different between monitoring years in the water bodies *($p < 0.05$)*

Phosphorus has a great role in biological metabolism, is an essential nutrient element, and plays a crucial role in photosynthesis and other processes in plants and algae (HENEASH et al. 2021). However, the presence of phosphorus in the form of PO_4^{3-}-P in the aquatic environment is the main cause of eutrophication (NDUKA et al. 2008). The research results show that the concentration of PO_4^{3-}-P in the water bodies of the conservation area has a relatively low value and was still within the allowable limit of QCVN 08-MT:2015/BTNMT. The average TP concentration ranged from

0.13 ±0.07–0.29 ±0.27 mg/L and was high in the canals and rice fields. There are signs of a rise from 2021 to 2022. Specifically, the concentration of PO_4^{3-}-P in water bodies in 2019–2022 ranges from 0.01 ±0.02–0.02 ±0.03 mg/L. The statistical analysis results show that PO_4^{3-}-P concentration between water bodies significantly differed ($p < 0.05$).

Iron (Fe^{2+}) and aluminum (Al^{3+}). The concentrations of Al^{3+} in the studied water bodies have an average value ranging from 2.58 ±2.15–145.04 ±213.93 mg/L (Figure 8). Al^{3+} concentration in the habitat water was the highest among the studied water bodies. The results also showed that the Al^{3+} concentration in each water body fluctuated over the years with statistically significant differences ($p < 0.05$). The results of the study in the period 2019–2021 were similar to the previous record of Ni (2018), which reported that the Al^{3+} content ranged from 2.85–21.25 mg/L. However, the significant increasing trend of Al^{3+} content in 2022 could be explained by the dredging of deep alum soil to create channels/dykes in the conservation area, making a closed water body leading to a potential alum soil layer leaching into canals in the conversation area's habitats. The average concentration of Fe^{2+} in water bodies ranges from 2.17 ±2.74 to 5.25 ±3.69 mg/L. In aquatic habitats, rice fields, intra-field canals, and peripheral canals, Fe^{2+} concentration fluctuates in the range of 2.34–4.58 mg/L, 0.17–6.12 mg/L, 1.52–8.89 mg/L, 0.07–6.46 mg/L, respectively. Fe^{2+} content in water tends to be highly concentrated in the peripheral canal, increasing gradually from 2019–2021 and decreasing in 2022. Fe^{2+} concentration in the study area is high, mainly because acidic soil releases Fe^{2+} into the water. The analysis results also show that the Fe^{2+} concentration fluctuates in each water body over the years with statistically significant differences ($p < 0.05$). According to Minh et al. (2006), potential acid sulfate soils will have high FeS_2 content, so when FeS_2 is oxidized, Fe^{2+} is released. According to Dong et al. (2015), water contaminated with iron is water with low pH, consistent with the pH results in the study area, then the water will have a fishy smell and much yellow dirt. The Fe^{2+} content in the study is thought to have no significant effect on growth and development in the habitats in the reserve, but it is not suitable for rice cultivation (Giao et al. 2020). The analysis results illustrate that water quality in the study area tended to be contaminated with aluminum.

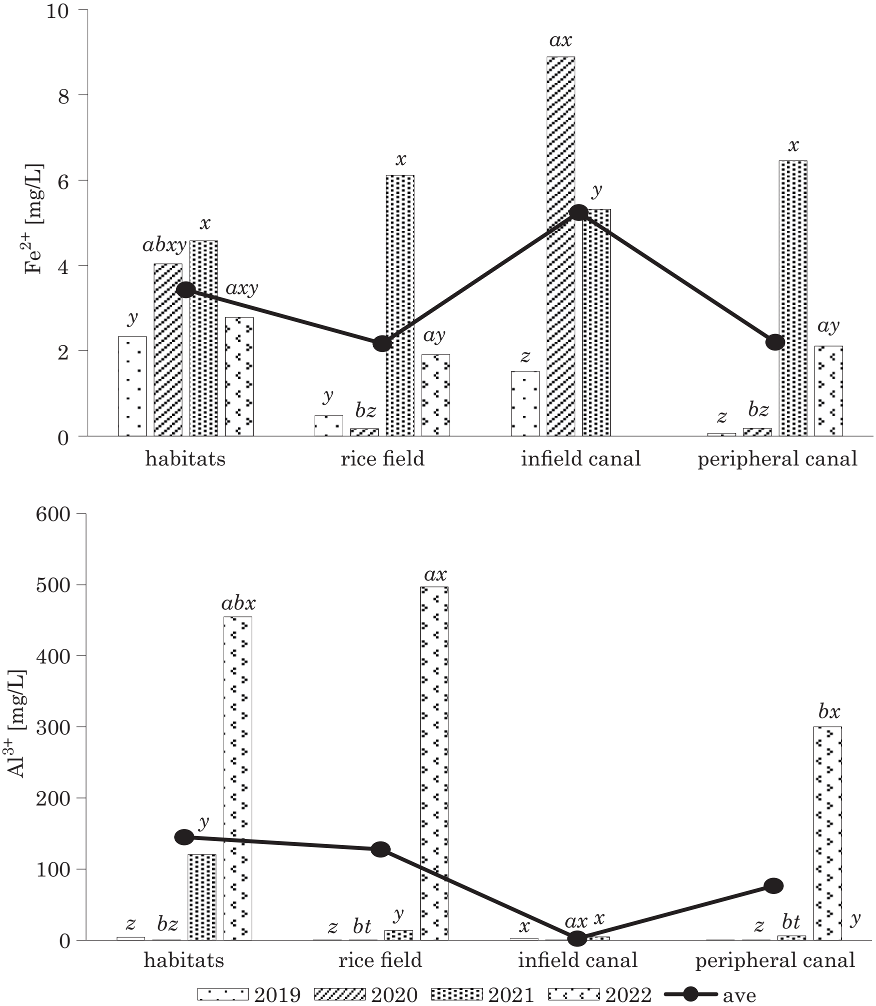


Fig. 8 Variation of iron and aluminum in the period of 2019–2022 in the conservation area
Explanations: *a, b* are statistically significant differences between water bodies in the same monitoring year ($p < 0.05$), and *x, y, z, t* are significantly different between monitoring years in the water bodies ($p < 0.05$)

Correlation among surface water parameters in the conservation area

Pearson correlation analysis was performed from data from 14 parameters in the water bodies, as detailed in Table 1. Table 1 shows that pH was closely correlated with most parameters, with negatively correlated with EC (-0.717), salinity (-0.639), DO (-0.354), and positively correlated with turbidity (0.630), TSS (0.673), COD (0.592), NH_4^+-N (0.519), TP (0.626). EC was strongly correlated with salinity (0.934), consistent with research results.

Table 1

Correlation of surface water quality variables

Parame-ters	pH	EC	Sal	Turb	TSS	DO	BOD	COD	NH_4^+-N	NO_3^--N	PO_4^{3-}-P	TP	Fe^{2+}	Al^{3+}
pH	**1**	–	–	–	–	–	–	–	–	–	–	–	–	–
EC	-0.717**	**1**	–	–	–	–	–	–	–	–	–	–	–	–
Sal	**-0.639****	**0.934****	**1**	–	–	–	–	–	–	–	–	–	–	–
Turb	**0.630****	**-0.495****	**-0.443****	**1**	–	–	–	–	–	–	–	–	–	–
TSS	**0.673****	**-0.514****	**-0.475****	**0.508****	**1**	–	–	–	–	–	–	–	–	–
DO	-0.354*	**0.414****	**0.354***	-0.212	-0.283	**1**	–	–	–	–	–	–	–	–
BOD	0.217	-0.059	-0.045	0.128	0.087	-0.186	**1**	–	–	–	–	–	–	–
COD	**0.592****	**-0.444****	**-0.380***	**0.356***	**0.484****	**-0.319***	-0.143	**1**	–	–	–	–	–	–
NH_4^+-N	**0.519****	-0.124	-0.096	**0.557****	**0.512****	-0.188	0.149	**0.454****	**1**	–	–	–	–	–
NO_3^--N	0.084	-0.248	-0.274	0.058	0.271	-0.101	0.076	-0.219	0.019	**1**	–	–	–	–
PO_4^{3-}-P	0.145	0.035	0.118	0.036	0.035	-0.229	**0.775****	-0.149	0.139	0.044	**1**	–	–	–
TP	**0.627****	**-0.414****	-0.300	**0.492****	**0.571****	**-0.322***	**0.349***	**0.428****	**0.535****	-0.006	**0.505****	**1**	–	–
Fe^{2+}	0.094	0.227	0.291	0.056	0.097	-0.138	0.019	**0.387***	**0.427****	-0.217	0.021	0.286	**1**	–
Al^{3+}	-0.082	0.159	0.205	-0.206	-0.209	-0.046	**0.637****	-0.249	-0.053	-0.081	**0.756****	0.065	0.024	**1**

Explanations: ** correlation is significant at $p < 0.01$ level; * the correlation is significant at the level $p < 0.05$

Meanwhile, both EC and salinity showed a weak negative correlation with turbidity and COD. EC also appeared to have a weak negative correlation with TP (-0.414). For turbidity and TSS, there was a positive correlation with COD (0.356, 0.484), NH_4^+-N (0.557, 0.512), and TP (0.492, 0.571). In addition,, turbidity also has a positive correlation with TSS (0.508). TSS appeared to have a weak and moderate positive correlation with organic pollutants (COD) and nutrient pollutants (NH_4^+-N, TP). DO is negatively correlated with COD and TP, with correlation coefficients of -0.319 and -0.322, respectively. Decomposing organic compounds and nutrients has contributed to reducing dissolved oxygen in water. The research results also show that organic pollutants and nutrients positively correlate. It is shown that they have a common origin, which could be derived from the discharge of domestic wastewater, agricultural runoff, and the use of fertilizers in farming in the study area. In addition, COD and NH_4^+-N have a weak correlation with Fe, respectively; BOD and PO_4^{3-}-P were strongly correlated with the formation of Al^{3+} in water. The correlation coefficient between the study area's surface water environment variables is significant ($p < 0.01$). Besides the factors analyzed in the study, a previous report by Tran et al. (2019) indicated that threats from climate change, such as drought, hydrological change, and inundation due to sea level rise, could significantly affect protected areas because of the low adaptive capacity of conservation areas.

Clustering surface water quality in the study area

Cluster analysis (CA) was performed from the data on eight monitoring locations in 2022 in order to find monitoring locations with similar characteristics, which gathered into a group, while sites with different physical and chemical characteristics will form separate groups.

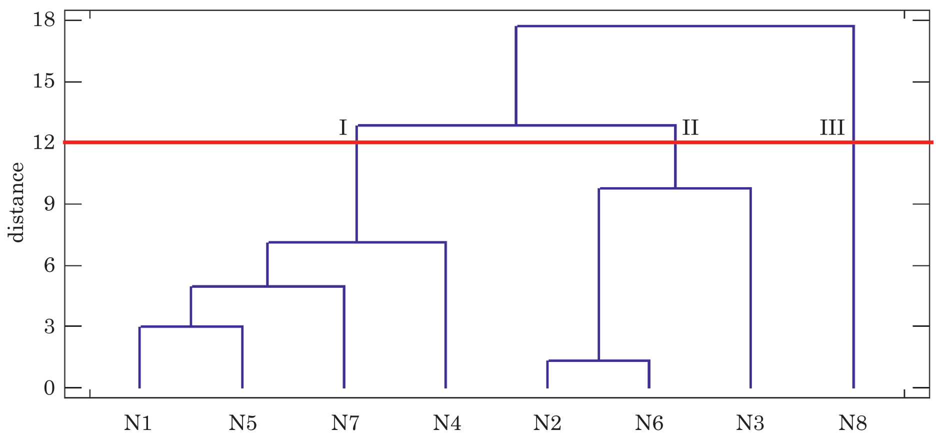


Fig. 9. Clustering surface water quality in the study area

The cluster analysis results formed three groups of surface water quality (Figure 9). Group I was established by four locations (i.e., N1, N4, N5, and N7), where peripheral canals, Melaleuca – Eleocharis, Melaleuca, and rice fields are located. Similarly, N2, N3, and N6 have similar characteristics and were classified into Group II, while Group III only included one location. Group II indicated that all locations are located in conservation areas' habitats, namely Melaleuca – Eleocharis, Lepironia – Eleocharis, and Lepironia. On the other hand, N8 was also found in the Melalecu habitat; however, this location is planned for the Melaleuca plantation, thereby, it could be affected by soil disturbance, leading to water quality characterized by high dissolved ions and low turbidity. The remaining locations have high levels of total suspended solids and organic matter. Based on the analysis results, it could be seen that the monitoring network of water quality in the conservation area was suitable for the status and activities of the conservation since the monitoring was carried out.

Conclusion

The research results show that the surface water environment at Phu My Species-Habitat reserve is acidic, and iron and aluminum are high in the water. Nutrient pollutants (NO_3^--N and PO_4^{3-}-P) are relatively low. Organic pollutants (BOD and COD) decreased in 2022 compared to 2021. In general, organic and nutrient pollution in the reserve is not high and has not significantly affected the life of aquatic plants and animals. Surface water quality in the reserve is being well managed for the development of Lepironia and Eleocharis. Pearson analysis results show that organic pollutants and nutrients in water have a positive correlation with each other, having the same origin from the discharge of domestic wastewater agricultural runoff in the study area. CA analysis results demonstrate that the monitoring system in the conservation was suitable for evaluating water quality. It could be applied to monitoring water quality annually in the future.

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