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Fluctuation of Water Regime and Its Influence on Surface Water Quality in Tram Chim National Park, Dong Thap Province, Vietnam

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ABSTRACT

The study was conducted to assess surface water quality in Tram Chim National Park (TCNP), Dong Thap Province, Vietnam using multivariate statistics. Water samples were collected at 10 different habitats in the national park in the rainy season and dry season to analyze the parameters of temperature (T), pH, electrical conductivity (EC), turbidity, dissolved oxygen (DO), chemical oxygen demand (COD), ammonium ($N\text{-}NH_4^+$) and orthophosphate ($P\text{-}PO_4^{3-}$), and water depth were measured monthly from January to July. The water regime is kept constantly high, affecting the water quality and biodiversity of the TCNP. The results show that the pH in the national park was in the neutral range and contaminated with COD and $N\text{-}NH_4^+$. The water quality in the fish pond and rice field habitats significantly differed compared to the remaining habitats. The result of CA also illustrates that the water quality in fish ponds and rice fields (in the buffer zone) is different from other habitats (in the protected zone) due to water exchange frequency and human activities. High pH value and organic matter content in water can affect the growth of organisms, especially Eleocharis species, an important food source for cranes. Therefore, research on the operating mechanism of sluices to have solutions to improve water quality to meet the requirements of preserving and restoring biodiversity is necessary.

Keywords: organic matter, water regime, water quality, Tram Chim National Park.

INTRODUCTION

Tram Chim National Park (TCNP) covers an area of 7,313 hectares with five zones, namely A1, A2, A3, A4, and A5, has different functions. TCNP is an open ecosystem with six plant communities, including *Eleocharis dulcis, Oryza rufipogon, Ischaemum rugosum, Panicum repens, Nelumbo nucifera, Melaleuca cajuputi* (Nga & Thuy, 2012). These habitats have created a typical ecosystem of the Dong Thap Muoi region; they develop themselves in harmony with the natural mechanism of flooding. Therefore, the hydrological regime is an important factor in the conservation of wetland ecosystems. Previously, the Tram Chim NP hydrological regime was managed in two forms (1) natural hydrology and (2) water regulation sluice system. However, due to dikes and water management to prevent forest fires, the vegetative accumulation capacity of plant communities has increased. This could exert a detrimental impact on the water quality, which acts as a precursor the biodiversity conservation.

Water quality in protected areas is greatly influenced by many factors such as vegetation, weather, climate, rainfall, and water management regime. Monitoring water quality in the national park is an important task for the sustainable management and development of the Tram Chim National Park. The physical, chemical and biological factors are often observed in the water environment, including temperature (T), pH, total suspended solids (TSS), turbidity, dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD), ammonium nitrogen ($N\text{-}NH_4^+$), orthophosphate ($P\text{-}PO_4^{3-}$), heavy metals (Fe, Al, Mn, Cr, and Cd), chloride (Cl^-), sulfate (SO_4^{2-}), pesticides, antibiotics, *E.coli* and coliform (Cho et al., 2009; Chounlamany et al., 2017; Zeinalzadeh & Rezaei, 2017). Therefore, the study was carried out to evaluate the hydrological control and water quality variation in the habitats. Besides that, the methods of cluster analysis (CA) are also used to assess spatial variation of water quality in Tram Chim National Park, Dong Thap province (Cho et al., 2009; Chounlamany et al., 2017; Zeinalzadeh & Rezaei, 2017). Research results provide important scientific information for effectively monitoring and managing surface water quality in the study area.

MATERIALS AND METHODS

Water sampling and analysis

Water samples were collected at 10 habitats, including *Ischaemum rugosum* (CM), *Panicum repens* (CO), *Nelumbo nucifera* (LS), *Eleocharis dulcis* (NO), *Oryza rufipogon* (LM), canal in protected zone (KL), canal in buffer zone (KD), fish pond (AC), rice field (RL), *Melaleuca cajuputi* (T) (Figure 1). Water samples were collected in the rainy season (2018) and dry season (2019) to analyze parameters including temperature (T), pH, conductivity (EC, µS/cm), turbidity (Tur, NTU), dissolved oxygen (DO, mg/L), chemical oxygen demand (COD, mg/L), ammonium ($N\text{-}NH_4^+$, mg/L) and orthophosphate ($P\text{-}PO_4^{3-}$, mg/ L). The pH, EC, DO, H and turbidity were measured directly in the field, while the COD, ammonium and orthophosphate parameters were analyzed in the laboratory using standard methods (APHA, 1998). Meanwhile, the water level was measured continuously from January to July. The criteria and analytical methods are presented in Table 1.

Data analysis

Water quality for each indicator was compared with the limit value of the National Technical Regulation on surface water quality (QCVN 08-MT:2015/BTNMT) (MONRE, 2015). The difference in water quality parameters of habitats was determined using one-way analysis of variance (One-way ANOVA) through IBM SPSS Statistics for Windows software, Version 20.0 (IBM Corp., Armonk, NY, USA). Multivariate analysis methods, including cluster analysis (CA), were used to assess water quality similarity in TCNP due to the influence of water control. CA was analyzed using Statgraphics Centurion version XVI software (Statgraphics Technologies Inc., Virginia state, USA).

RESULTS AND DISCUSSION

Current status of dyke and sluice system in Tram Chim National Park

Tram Chim NP currently controls and manages the water completely with sluices and

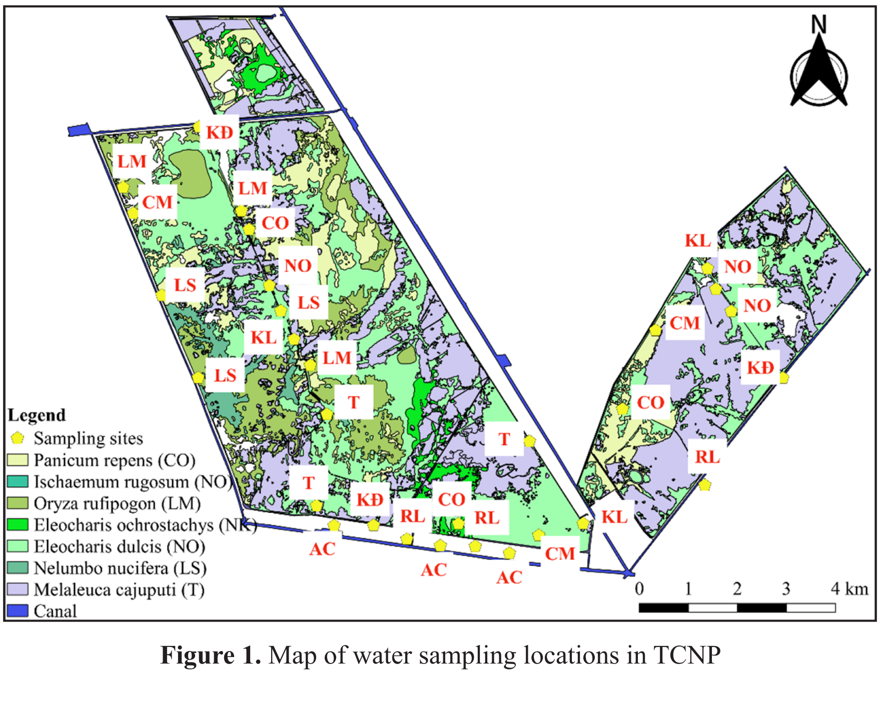

Figure 1. Map of water sampling locations in TCNP

Table 1. Water parameters and analytical methods

No.	Parameters	Unit	Analytical methods
1	Temperature (T)	°C	Temperature meter AD332 ADWA (SMEWW 2550B:2012).
2	Water depth (H)	m	Tape measures
3	pH		pH meter, Eutech Instrument pH6+ (TCVN 6492:2011)
4	Electrical conductivity (EC)	mS/cm	EC meter, Eutech Instrument pH6+ (SMEWW 2510B:2012)
5	Turbidity (Turb)	NTU	Turbidity meter
6	Dissolved oxygen (DO)	mg/L	DO meter, Aqualytic AL200xi (TCVN 7325:2016, ISO 5814:2012)
7	Chemical oxygen demand (COD)	mg/L	Titration method SMEWW 5220 C: 2012
8	Ammonium (N-NH_4^+)	mg/L	Colorimetric method (SMEWW 4500 NH3.B&F: 2012)
9	Orthophosphate (P-PO_4^{3-})	mg/L	Colorimetric method (Hach DR 4000/5000 Method 8048)

spillways with a closed dike system in the core zone and an outer dyke surrounding the buffer zone. A total of 12 sluices and spillways have been built to regulate hydrology. In which, zone A1 has 4 sluices (C1, C2, C3 and C4) and 2 spillways (C7 and C8); zone A2 has 2 sluices (C5 and C6); Zone A4 has 01 A4 sluice, and 01 A4 spillway; Zone A5 has 02 sluices (new A5 and A5 sluices) (Figure 2).

The National Park closes and opens sluices to regulate water inwards to enhance water exchange, attract aquatic products and store water in the dry season for fire prevention. The time to open the sluice (water in) is usually from July to August (at the beginning of the flood season). The time to close the sluice (keep the water) is from October to November (peak flood) when the water level in each area lowers to the allowable level to keep water. The sluices operation is carried out manually (staffing) and sluices milling (wooden material). In addition, establishing the analyzed and evaluated canals caused to obstacle the exchange of water, changing silt, nutrients, and fish with the surrounding environment (Tran & Barzen, 2016). However, the canals in the NP are made to prioritize water distribution and fire prevention according to policy management of the special-use forest system. In addition, these water controls have affected water quality and the typical vegetation of the area.

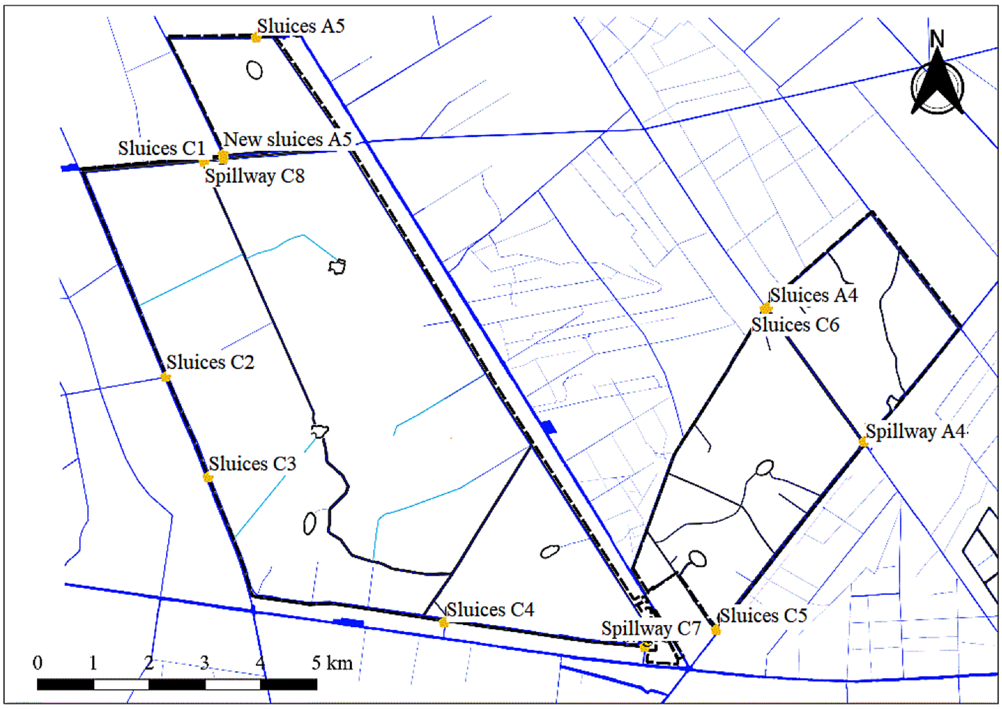

Figure 2. Distribution of canals, dikes and sluices in Tram Chim National Park

Current status of water level control in the dry season in Tram Chim National Park

Water level regulation in the dry season is carried out from January to June every year, according to the approved hydrological management scheme. Depending on the year's weather conditions, the hydrological regulation will be adjusted to suit the actual situation. Specifically, water management in the dry season at TC NP in the period 2018–2019 is shown in Figure 3. The proposed water level in the study was based on a previous report by Ni and Tuan (2015).

Hydrological fluctuations in the dry season in zone A1 were in the range of 160–202 cm. The proposed water level from January to June ranges from 60–143 cm. Water management in zone A1 from 2018 to 2019 was significantly higher than the proposed water level, about 59–102 cm on average. From January to June, the average water level in zone A2 for many years fluctuates around 153–196 cm, about 35–88 cm higher than the target water level. The suggested water level for the period was about 80–161 cm. Although this was a zone that did not record the presence of fires and was a fire focus zone, the water level was still kept at a very high level. Zone A3 has the average water level in the dry season, ranging from 156–200 cm, which was higher than that of the target water level, around 65–108 cm. This is a

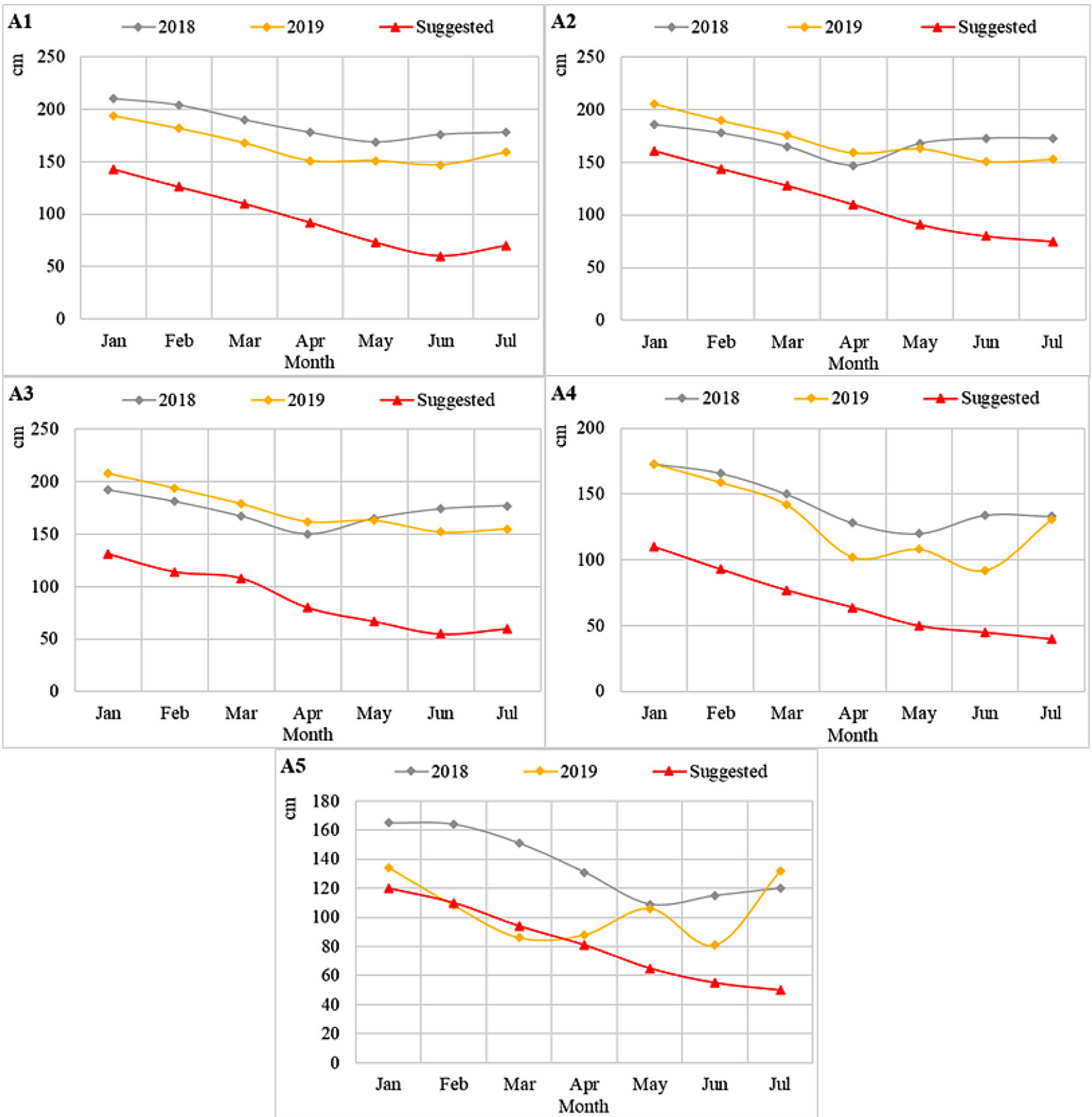

Figure 3. Current status of water management compared to target water level

zone to preserve and regenerate all typical habitats of Tram Chim NP for ecotourism development. Therefore, the proposed water level in this zone should ensure the recovery and development of the typical habitat of the NP in the dry season. Zone A4 is considered a habitat and provides food for cranes. However, based on actual data, it can be seen that the average water level at the beginning of the dry season ranged from 113–173 cm, still 51–92 cm above the target water level. In which, the lowest average difference was recorded in April. This shows that water management directly affects the number of *Sarus Cranes* in the NP. Because in recent years, the number of *Sarus Cranes* arrived later (April) than in the previous time (February). Therefore, the management should consider keeping the water level low to create favorable conditions for the living environment and the formation of Eleocharis atropurpurea tubers. In zone A5, the actual water level measurements in 2019 were lower than the proposed water level (from -2 to -8 cm). The average water level in many years ranged from 98–150 cm, and the average difference from the proposed water level was about 25–76 cm. In addition, Figure 3 shows that water level management in 2019 was not significantly different from the proposed water level. This data showed the effectiveness of the new sluice A5 (built-in 2019) in regulating the hydrological regime in the dry season; however, the trend of high water retention was still implemented to limit the risk of fire in this zone. Therefore, a new water level should be applied in this zone to ensure the crane's habitat and feeding ground maintenance. In general, areas A1, A2 and A3 have the highest kept water levels, followed by areas A4 and A5.

Variations of surface water quality of habitats in TCNP

From Figure 4, it is shown that the pH value in habitats varied from 5.73–7.70. pH values in the fish pond and rice field habitats were highest and lowest, respectively. No statistically significant differences in pH were observed in the habitats ($p>0.05$). The results of this analysis suggest that water storage in the dry season affected the pH conditions of the dominant species in the plant communities. In fact, high pH values can facilitate the invasion of other habitats, especially *Eleocharis ochrostachys*.

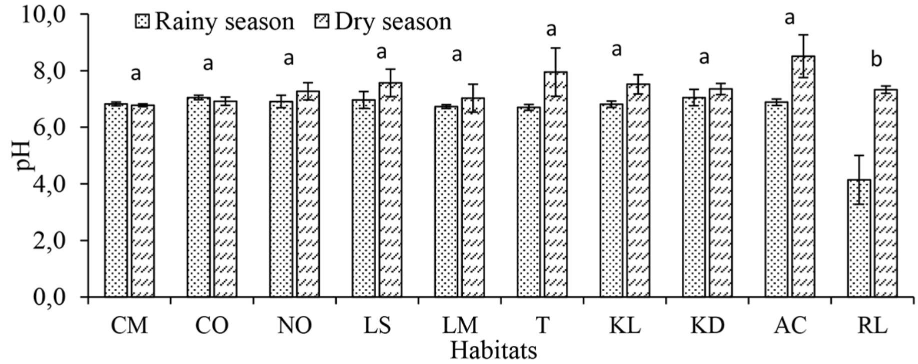

Figure 4. Variation of pH in habitats in TCNP

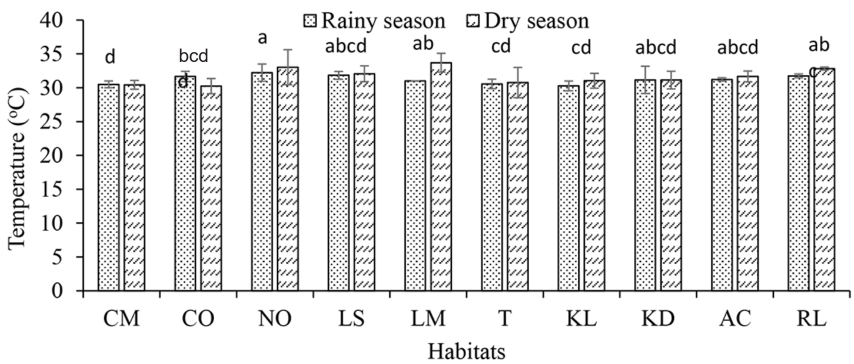

Figure 5. Variation of temperature in habitats in TCNP

Temperature monitoring results in the habitats in two seasons in the core and buffer zone areas were relatively stable, ranging from 30.23±1.12 to 33.7±1.39°C (Figure 5). When analyzing the differences in temperature fluctuations in habitats, the results showed that most of the habitats were statistically significant differences ($p<0.05$), specifically in the habitat of the CM and CO. In general, temperature fluctuations between monitoring locations were small (25–32°C), which is the best temperature range for the growth of aquatic organisms (Boyd, 1998).

Figure 6 showed that the electrical conductivity in water in AC and RL was highest in both seasons, with a range of 316±15–623±55 µS/cm and 303±16–533±61 µS/cm, respectively. High EC values can be attributed to the presence of ions under acidic soil conditions. In addition, it can be seen from Figure 6 that EC in the buffer zone was relatively high (fish pond habitat) and was significantly different from other areas ($p<0.05$). This difference mainly comes from farming practices. Meanwhile, there was almost no change in EC in the remaining habitats because farming does not affect these habitats.

In terms of turbidity, there was no statistically significant difference between the habitats ($p> 0.05$) (Figure 7). The two habitats, NO and LS, had the highest values in the rainy and dry seasons, respectively. Meanwhile, the melaleuca habitat had the lowest turbidity value in the two seasons. High turbidity in water can be attributed to the presence of high concentrations of suspended solids in the water. In addition, water flow factors, as well as weather factors, also contribute to the turbidity of the water.

The DO concentration in the fish pond habitat was highest, at about 19.53 mg/L, and there was a statistically significant difference compared to the remaining habitats (Figure 8). However, The DO concentration during the rainy season was relatively low, which could indicate that the water quality inside the NP has been affected due to the opening and closing process, leading to poor quality water outside entering the NP. Water with low DO content is often polluted and affects the growth of aquatic organisms. If this concentration were too low, aquatic organisms would be adversely affected (<3 mg/L) (Rubio-Arias et al., 2012).

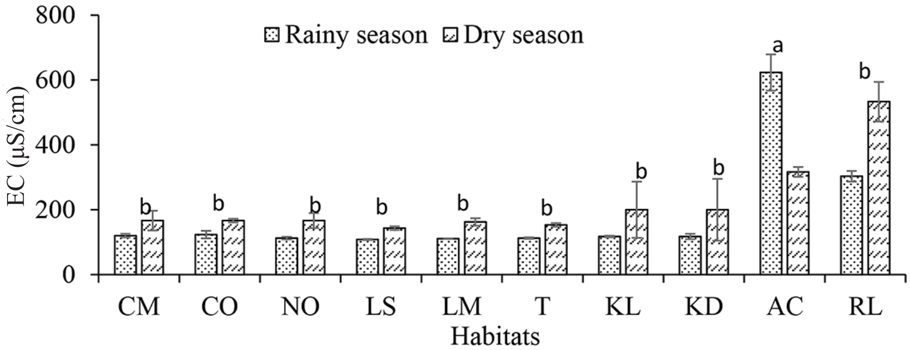

Figure 6. Variation of electrical conductivity in habitats in TCNP

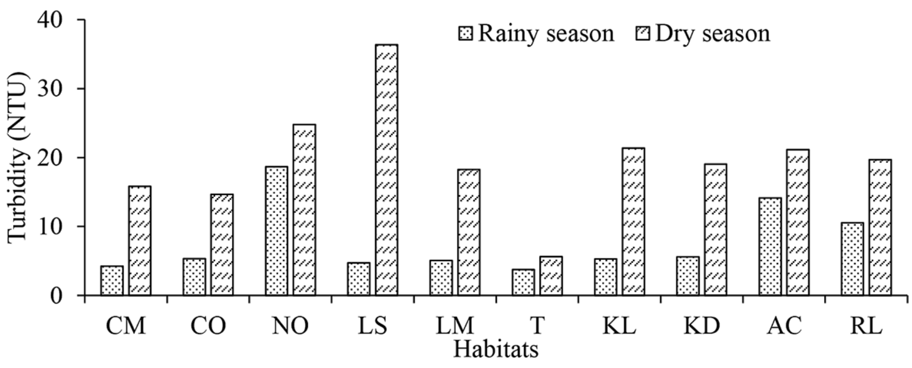

Figure 7. Variation of turbidity in habitats in TCNP

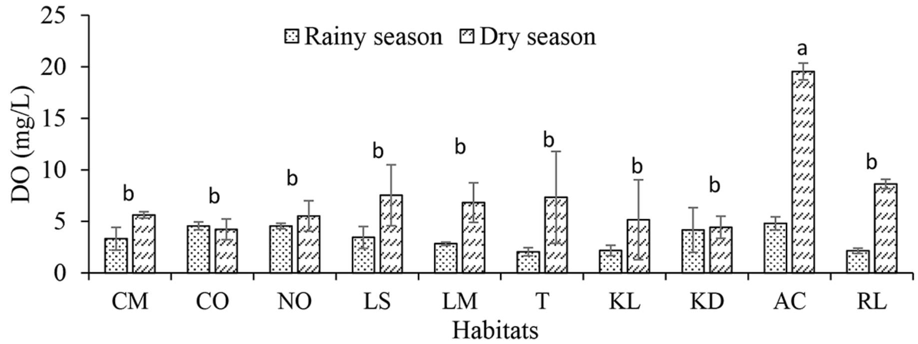

Figure 8. Variation of DO in habitats in TCNP

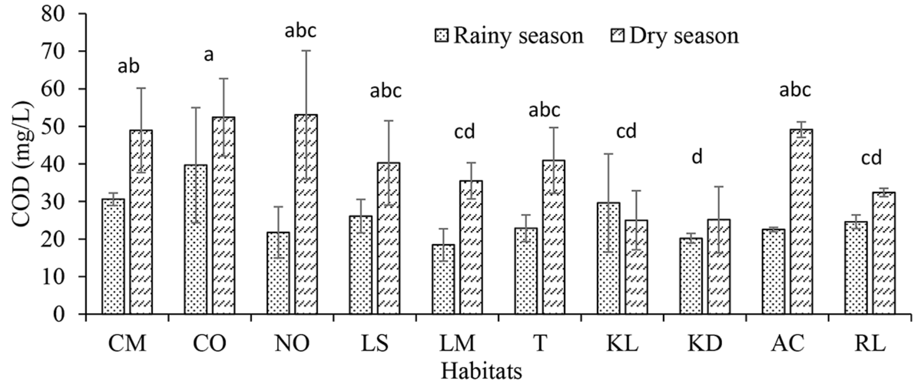

Figure 9. Variation of COD in habitats in TCNP

The average COD concentration in the habitats ranged from 22.67 to 46.03 mg/L, the highest in the CO habitat and the lowest in the KD habitat (Figure 9). The results showed that COD had a large difference between the habitats ($p< 0.05$). This indicates that water quality in the habitats was significantly affected by water retention that was too high compared to the target water level. Specifically, high water retention year-round made some species unable to adapt to die and accumulate a thick organic layer. The result is an effect on water quality in habitats with dense vegetation. The analysis results showed that the concentration of $N\text{-}NH_4^+$ in the habitats was relatively high and fluctuated with a range of 0.13–0.45 mg/L, especially in the dry season (Figure 10). In which, the highest value was recorded at RL habitat, which could be explained by the habitat being regularly supplemented with nutrients during the cultivation process. However, there was no statistically significant difference between the habitats in the study area ($p>0.05$). the concentration of $N\text{-}NH_4^+$ exceeded in the dry seasons compared to QCVN 08-MT:2015/BTNMT (0.3 mg/L), which has tended to be similar to COD.

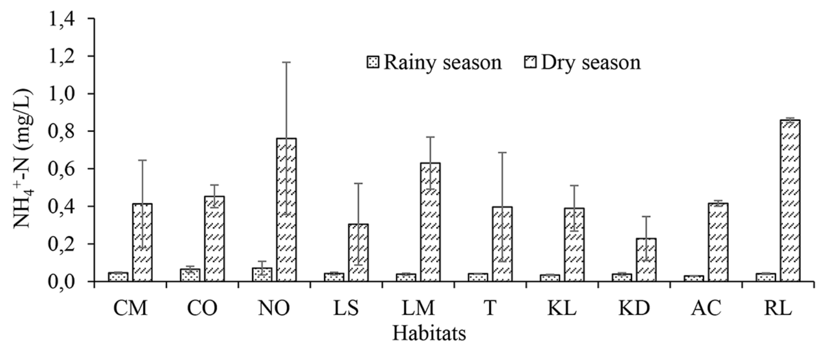

Figure 10. Variation of ammonium in habitats in TCNP

The concentration of P-PO_4^{3-} ranged from 0.64–2.40 mg/L, with the lowest and highest concentrations in fish ponds (Figure 11). The P-PO_4^{3-} concentrations in most habitats in the rainy season exceeded the allowable limit of QCVN 08-MT:2015/BTNMT- column A1 (0.1 mg/L). The difference in P-PO_4^{3-} concentration between habitats was not statistically significant ($p>0.05$). Nevertheless, water quality in habitats tended to be more contaminated with organic matter than nutrients.

Clustering surface water quality in TCNP

CA analysis results showed that the habitats are divided into five groups at Euclidean distances of 3.67 (Figure 12). The habitats such as LS, NO and LM were grouped (Group 5) due to similar water quality characteristics, such as high temperature and COD values. Group 4 was formed from the buffer and core canal habitats because these two habitats had relatively high-water quality similarities, especially EC, depth and COD. Besides, the COD in group 4 had the lowest value, showing that the water quality was less polluted with organic and inorganic substances than in other groups. A previous study also reported this (Siwiec et al., 2018). Habitats with the same water quality characteristics, such as turbidity, temperature and low pH, were classified into Group 3. This may indicate that natural factors mainly influence water quality in these habitats. Particularly in the two habitats, AC and RL were divided into two separate groups, including Group 1 and Group 2. These two groups were affected by human activities. Group 1 had the highest values of depth, DO and pH and P-PO_4^{3-}. In contrast, group 2 (rice field habitat) had the lowest depth value; EC and N-NH_4^+ were recorded as the highest compared to the habitats belonging to other groups. Residues of pesticides and nutritional sources during fish culture may be the main causes affecting water quality classification in these two habitats (Giao, 2020).

Meanwhile, in the rainy season, the clustering of habitats was also classified into five groups (Figure 13). Similar to the dry season, Group 1 and Group 2 also included two

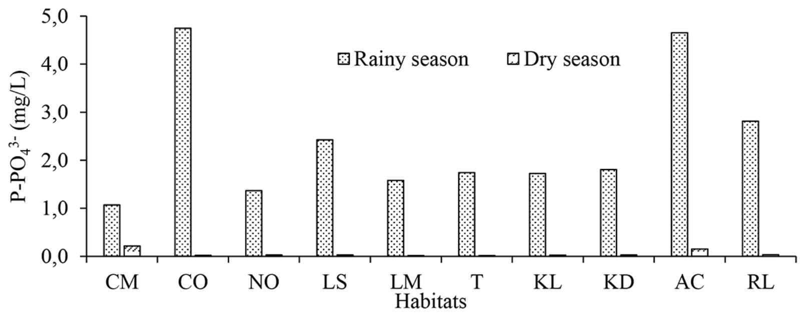

Figure 11. Variation of orthophosphate in habitats in TCNP

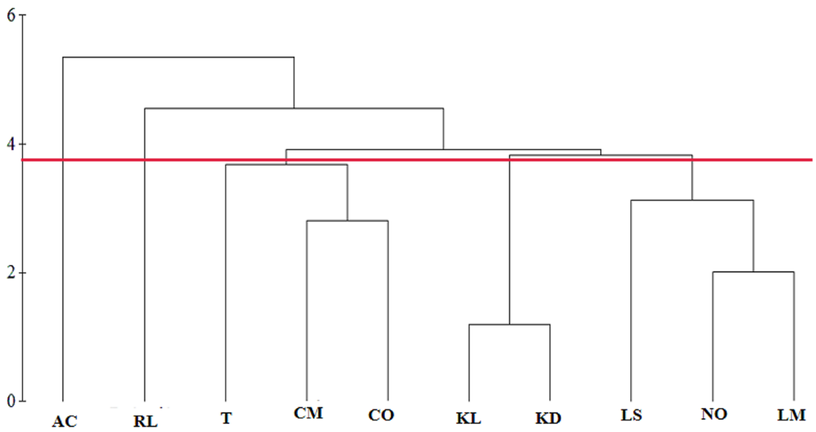

Figure 12. Clustering surface water quality in TCNP in dry season

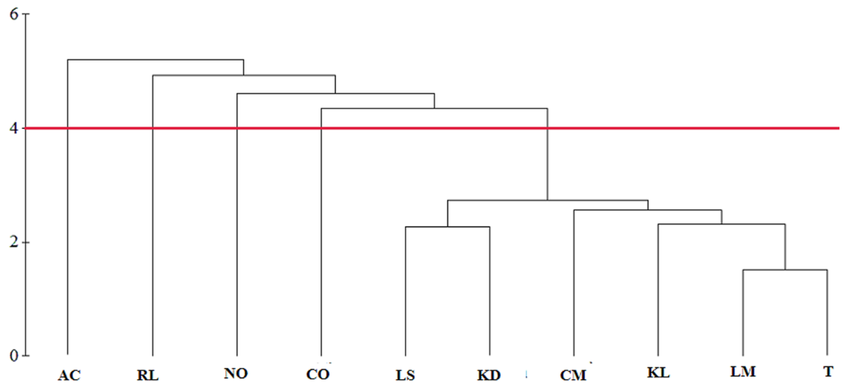

Figure 13. Clustering surface water quality in TCNP in wet season

habitats of AC and RL with average pollution levels. Group 3 (NO habitat) was classified based on factors such as temperature, DO, turbidity and $N\text{-}NH_4^+$; Group 4 was characterized by COD and $P\text{-}PO_4^{3-}$ similarity. The remaining habitats (Group 5) can be assessed at a lower pollution level than the other groups; however, the value DO in these habitats was relatively low. This may affect the growth of aquatic life in the study area.

CONCLUSIONS

The water management regime in the NP is always kept at a higher level than the target water level, affecting the natural water exchange process and the periodic inundation of the NP. The results show that the water quality in TCNP was contaminated with organic matter and nutrients ($N\text{-}NH_4^+$ and $P\text{-}PO_4^{3-}$), and the water pH is neutral. The pH value has been significantly affected by water control processes in the NP, leading to the risk of species diversity and purity loss in some habitats. Most parameters differed significantly between the habitats, except for the nutritional ones. CA analysis results showed that water quality between wet and dry seasons did not change significantly, and the classification of habitats was mainly based on the surface water parameters analyzed in the dry season. The surface water quality in the fish pond and rice fields differed from other natural habitats in the TCNP, with the possible causes of the difference in water depth and physical and chemical processes occurring in nature, partly from farming and fish farming activities.

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