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EVALUATING SOIL AND WATER QUALITY IN PHU MY SPECIES AND HABITAT CONSERVATION AREA, KIEN GIANG PROVINCE

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Abstract

The study aims to assess the quality of soil and water environment in Phu My Species and Habitat Conservation Area, Kien Giang province. Water samples were collected at 16 sites in 7 different habitats (Lepironia articulata - Eleocharis dulcis habitat, Lepironia articulata - Melaleuca cajuputi habitat, Lepironia articulata - Ischaemum rugosum habitat, Eleocharis dulcis habitat, Lepironia articulata - Eleocharis ochrostachys habitat, Eleocharis ochrostachys habitat, Rice field habitat) and four canals in the area for analysing pH, dissolved oxygen (DO), chemical oxygen demand (COD), total nitrogen (TN), total phosphorus (TP), aluminum (Al^{3+}) and iron (Fe^{2+}). Water level, velocity and flow discharge in the canals were also measured. Soil was sampled at 15 sites in different habitats for analysing pH, conductivity (EC), organic matter (OM), TN, TP, available phosphorus (P_2O_5), available potassium (K_2O), and Al^{3+}. Results showed that water quality of the study area had low pH, relatively high concentration of Al^{3+} and low nutrient (TP). Saline water intruded into canals inside the conservation area. The soil was characterized as acid sulfate soil since pH was low and acidity and exchangeable Al^{3+} were high. The concentration of TP, P_2O_5, TN and K_2O in soil ranged from low to medium whereas OM level was high. Canals in the conservation area are unevenly distributed. The average flows and velocities varied between locations, but the levels of water changed slightly. Low water exchange may lead to water pollution in the area. The study provides useful information on soil and water properties for sustainable management and development in Phu My Species and Habitat Conservation Area.

Keywords: Acid sulphate soil; Conservation; Habitat; Organic matter; Soil quality; Water quality.

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1. Introduction

Phu My Species and Habitat Conservation Area (PMSHCA) is located in Phu My commune, Giang Thanh district, Kien Giang province. The conservation area is 1,070.28 ha dividing into three functional areas including Zone I (Administrative - Service Area) with a total area of 24 ha; Zone II (Ecological Restoration Area) 435 ha and Zone III (Strictly Protected Area) 611.28 ha. According to Triet et al (2001), the Ha Tien plain, including Phu My commune, consists of major soil groups including mountainous soils, saline soils, acid sulfate soils, peat soil, small gray soil and red-yellow soils and sandy soils. In which, acid sulfate soil group occupies the most area in Phu My commune. PMSHCA is a form of primitive wetland that the last remaining fragments of grassland occupying the largest area in the Vietnamese Mekong Delta (Triet et al., 2001). This area is not only high biological productivity, but also species diversity in both plants and animals (Triet et al., 2004; Ni and Triet, 2013). A recent study reported that the number of species in PMSHCA is 456 species, including 47 species of higher plants, 126 species of birds, 30 species of fish, 13 species of amphibians, 72 species of algae, 67 species of zooplankton, 8 species of zoobenthos, 39 species of spiders, and 54 aquatic insects. Biodiversity maps have been established placing a strong emphasis on the locations of cranes (*Grus antigone sharpii*) and their feeding grounds (Triet et al., 2004; Ni and Triet, 2013). The conservation area is also associated with the livelihoods of the people, especially the exploitation of Lepironia grass (Ni and Triet, 2013). The environment includes natural, biological and communal elements). For sustainable

development of the conservation area, the environmental quality of soil and water, the two environmental components directly related to biodiversity at the area, should be clearly recognized. This study aimed to assess the quality of water and soil in PMSHCA, Kien Giang Province in order to provide important information for sustainable development of the conservation area.

2. Materials and methods

2.1. Water sampling and analysis

Water samples were collected at 16 sites (Figure 1a, denoted from T1 to T16) in 7 different habitats (*Lepironia articulata - Eleocharis dulcis, Lepironia articulata - Melaleuca cajuputi, Lepironia articulata - Ischaemum rugosum, Eleocharis dulcis, Lepironia articulata - Eleocharis ochrostachys, Eleocharis ochrostachys,* Rice field) and 5 canals (Canal HT6, Canal 1, Canal 2, Canal Nuoc Ngot, and Canal Kenh Moi) of PMSHCA. pH and dissolved oxygen (DO, mg/L), electrical conductivity (EC, µS/cm) were measured directly in the field, while chemical oxygen demand (COD, mg/L), total nitrogen (TN, mg/L), total phosphorus (TP, mg/L), aluminum (Al^{3+}, mg/L) and iron (Fe^{2+}, mg/L) were analyzed at the Environmental Analysis Lab, Department of Environmental Science, College of Environment and Natural Resources, Can Tho University using standard methods (APHA, 1998).

2.2. Soil sampling and analysis

Soil samples were collected at 15 sites, symbolized from M1 to M15 (Figure 1b). Soil samples were dried at room temperature, pulverized and then sieved through a 0.5 mm pore size mesh for analyzing pH, electroductivity (EC, µS/cm), organic matter (OM, %), total nitrogen (TN, %), total phosphorus (TP, %), available phosphorus (P_2O_5, mg/kg), available potassium (K_2O, meq/100g soil), total acidity (meq H^+/100g soil) and exchangeable aluminium (Al^{3+}, mg/kg). pH and EC were extracted with distilled water, ratio 1: 5 (soil/water), then determined by pH and EC meters, respectively. Organic matter was analyzed by Walkley-Black dichromate (Walkley-Black dichromate wet oxidation method), TN was analyzed by Kjeldahl method, and TP was analyzed by colorimetric method after digesting the samples with a mixture of H_2SO_4 and $HClO_4$. Mobile phosphate (P_2O_5) was analyzed by Olsen method. Available potassium was determined using atomic absorption spectrometer (AAS, Agilent, AA240). Total acid was extracted with potassium chloride (KCl) and titrated with 0.01N NaOH solution. Aluminum was extracted with KCl and then titrated using 0.005N H_2SO_4.

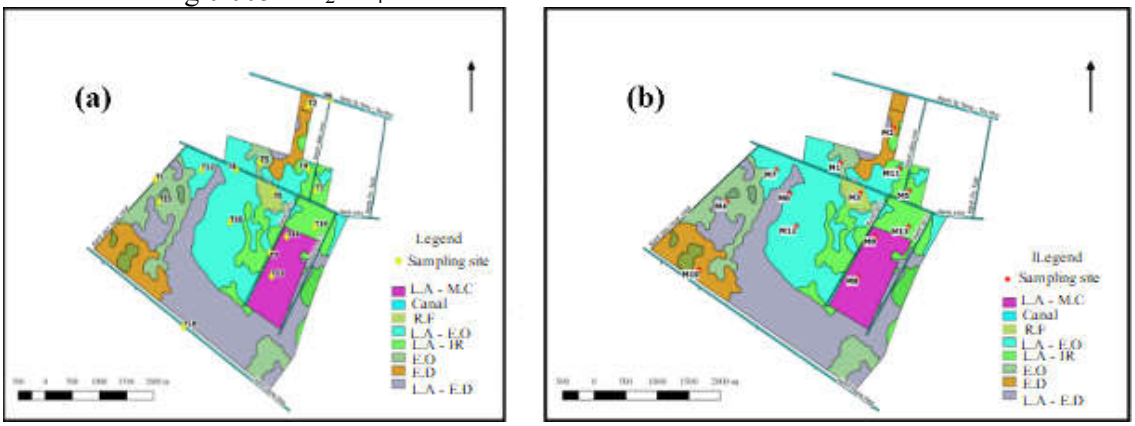

Figure 1: Locations of water (a) and soil sampling (b) at Phu My Species - Habitat Conservation Area.

Notes: L.A: Lepironia articulata; E.D: Eleocharis dulcis; M.C: Melaleuca cajuputi; I.R: Ischaemum rugosum; E.D: Eleocharis dulcis; E.O: Eleocharis ochrostachys; R.F: Rice field

2.3. Measurement of water levels in canals

Measurement of water levels in the canals was performed using bamboo scales at 6 locations (Figure 3). The bamboo stems were pre-scaled. The scaled bamboos were

perpendicularly placed into the canals' bottom sediment. Changes of water levels were observed by looking at the scales on the bamboos at 7 am, 10 am, 13 pm and 16 pm.

2.4. Measurement of flow velocity

Flow velocity in canals was measured using a flow meter device that is based on the rotation numbers of the rotor (Flow velocity meter model LS68) in a time period. Velocity is calculated by Equation 1:

$$V = 0.6756 * n + 0{,}0039 \text{ (m/s)} \quad (1)$$

where V is velocity at the field, n is the numbers of rotation of the rotor in one second; n = RT (m/s), where R is the total numbers of rotation of the rotor in the period of time T, T is the time (in second) of the measurement of flow velocity.

2.5. Measurement of flow discharge

Flow discharge was calculated by analytical method using Equation 2:

$$Q = \left(b_1 \frac{h_1}{2}\right) K_b V_{1+} \left(b_2 \frac{h_1+h_2}{2}\right)\left(\frac{V_1+V_2}{2}\right) + \left(b_3 \frac{h_2+h_3}{2}\right)\left(\frac{V_2+V_3}{2}\right) + \left(b_4 \frac{h_3}{2}\right) K_b V_3 \quad (2)$$

Where, Q is flow discharge of the total cross-section (m^3/s); b1, b2, b3, b4 (Figure 2) is the distance between water column (m); h1, h2, h3, h4 (Figure 2). Depth of water column (m); Kb: Coefficient indicating the influence of river banks on velocity (0.85); $\left(b_1 \frac{h_1}{2}\right)$, $\left(b_2 \frac{h_1+h_2}{2}\right)$:: Partial area ($m^2$); $K_b V_1$, $\left(\frac{V_1+V_2}{2}\right)$: average flow discharge of every partial area (m/s).

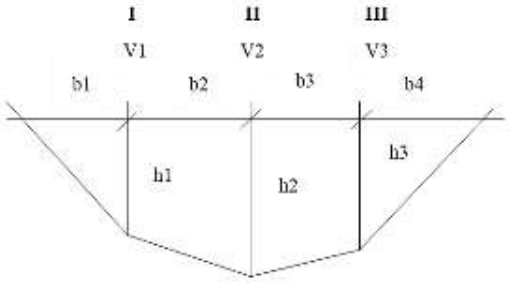

Figure 2: Diagram demonstrating calculation of flow discharge

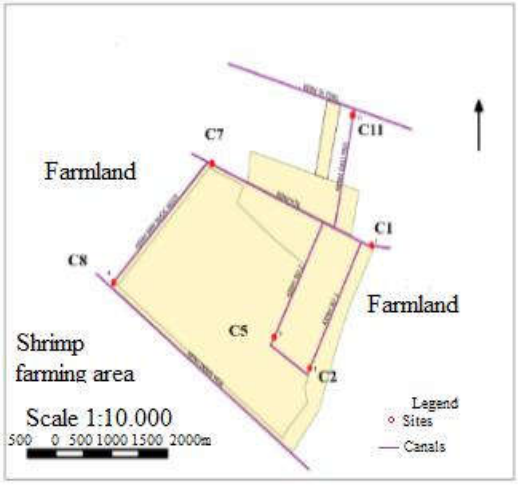

***Figure 3*: Locations of measurement water level, flow velocity and discharge at Phu My Species - Habitat Conservation Area. C1 and C7 were on Canal HT6, C2 was on Canal 1, C5 was on Canal 2, C8 was on Canal Nuoc Ngot, and C11 was on Canal Kenh Moi**

3. Results and discussion

3.1. Water quality

Water depths of the habitats ranged from 1.67 - 237.5 cm (Fig. 4). The depths of water at habitats were not significantly different, except the rice field (very low water depth) and the canals

(very high water depth). Water level is one of the decisive factors for diversity of flora and fauna at the conservation area. Lepironia grass, the important grass for livelihood of the local community, is highly productive at high water depth conditions. Thus, managing water depth plays an important role in the management of the conservation area.

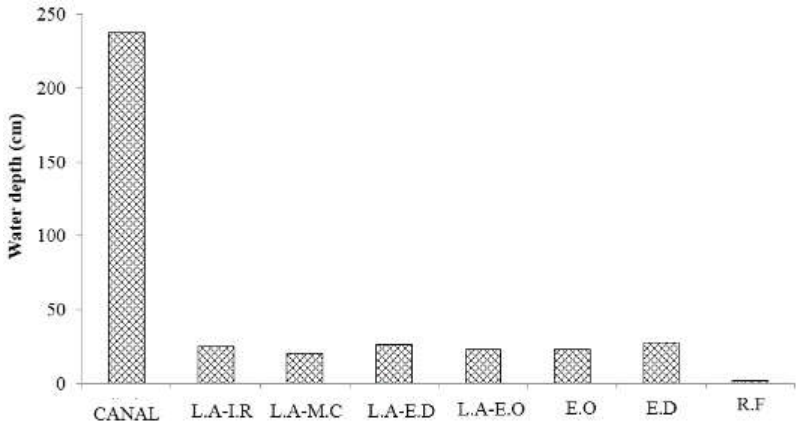

Figure 4*: *Water depth at the habitats in the conservation area

Notes: L.A: Lepironia articulata; E.D: Eleocharis dulcis; M.C: Melaleuca cajuputi; I.R: Ischaemum rugosum; E.D: Eleocharis dulcis; E.O: Eleocharis ochrostachys; R.F: Rice field

Water levels in canals were different. The average water level was 1.57 m at Canal HT6 (C1), 0.37 m at Canal 1 (C2), 2.12 m at Canal 2 (C5) and Canal HT6 (C7), 0.23 m at Canal Nuoc Ngot (C8) and 1.77 m at Canal Kenh Moi (C11). Canal 1 and Canal Nuoc Ngot had low water levels compared to the others (Figure 5).

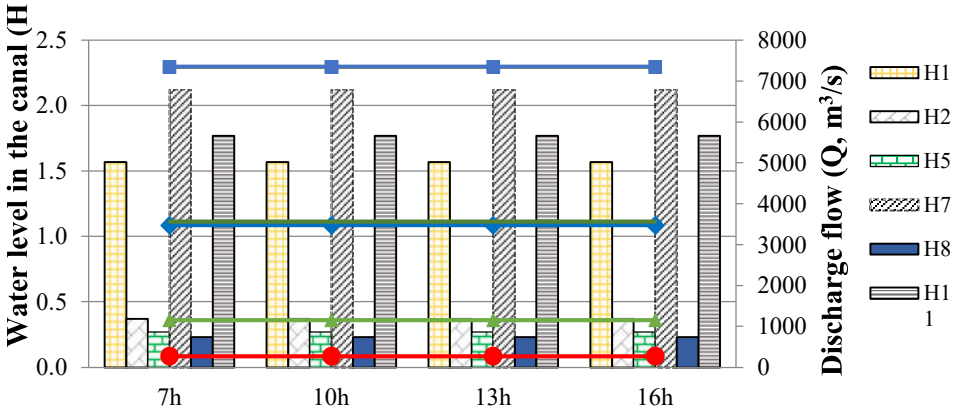

Figure 5: Water level and flow discharge in canals in Phu My Species and Habitat Conservation Area

The flow discharge varied among study sites. The smallest discharge was found at C5 (204 m^3/s) while the highest value was found at C8 (5523 m^3/s). The flow velocity was found lowest at C11 (51 m/s) and highest at C2 (568 m/s). The study area is less influenced by the jemi-diurnal tidal regime; thus, only small change of water level was observed at different sampling time (7am, 10am, 13pm and 16pm). Water level, discharge and velocity were different among the canals; however, water level almost unchanged within a day. This could lead to poor water exchange, resulting in water stagnant and water pollution.

Water temperature at study sites was from 23.8°C to 26.6°C and the annual air temperature of the conservation area was in the range of 27 - 27.5°C. Water temperature was less varied compared to that of the air. The temperature was in the good range for growth and development of organisms (Boyd, 1998).

Table 1 showed that pH value in water at the habitats ranged from 3.31 to 5.12. The highest pH value was 5.12 at the canal. Previous studies reported that the mean pH at PMSHCA was 5.64 (Ni and Triet, 2013) and 4.02 (Thia, 2007), indicating the increase of pH value over years. EC values at the habitats and canals were not different ranging from 310.50 to 1,521.50 µS/cm. The largest EC was found at the canal (1,521.50 µS/cm) and the smallest at the habitat dominated by *Eleocharis ochrostachys* (310.5µS/cm). Thia (2007) found the average EC value at the canals in the conservation area was 1,036.7µS/cm which is lower than the EC found in canals in this study. The differences in EC values and the increasing trend in this study may be due to the presence of iron, aluminum and manganese salts

Salinity at the habitats ranged from 0.20 to 2.05 ‰. The highest salinity was found in canals while the lowest salinity was found in *Eleocharis ochrostachys* habitat and rice field habitat. Previous study found that salinity in the habitats of PMSHCA only ranged from 0.00 to 0.01 ‰ (Ni and Triet, 2013) which is much lower than the results of this study. High salinity found in this study could be caused by saline intrusion or by the influence of adjacent shrimp farms. This is an issue that should be considered in the management and conservation of biodiversity in PMSHCA.

Dissolved oxygen (DO) highly varied among the habitats, ranging from 2.21 to 8.48 mg/L. Previous research showed that DO concentration at the habitats ranged from 4.58 from 5.55 mg/L (Ni and Triet, 2013), within the range of DO measured in this study. DO in the canals tended to be higher than those in the other habitats. In the conservation area it was covered high by plants that limited the photosynthesis of aquatic plants, which could be considered as a cause of the low dissolved oxygen content in the area. In addition, the measurement process may be affected by objective factors (time, wind).

COD ranged from 5.65 to 23.47 mg/L exceeded the permissible level regulated by National technical regulation on surface water quality (QCVN 08-MT:2015/BTNMT, Column A1). Encroachment on protected area for grazing cattle, poultry and agricultural cultivation affected canal water quality and other habitats in the conservation area. In addition, the daily activities of the local community have also contributed to organic and inorganic pollution in the study area, especially for rice cultivation area.

Table 1. Water quality at the Phu My Species and Habitat Conservation Area

Habitat	**Site**	**pH**	**DO**	**COD**	**TP**	**Fe^{2+}**	**TN**	**Al**	**EC**	**S**
		-	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**µS/cm**	**%**
Canal	T7	2.95	6.27	6.26	0.015	1.03	5.25	23.60	528.0	0.34
Canal	T8	4.80	5.75	13.56	0.029	1.35	4.90	19.80	392.0	0.25
Canal	T9	6.60	4.72	29.30	0.155	1.32	4.55	4.40	166.0	0.11
Canal	T10	6.13	5.90	10.13	0.023	0.65	6.65	0.30	10000.0	7.50
Mean		**5.12**	**5.66**	**14.81**	**0.056**	**1.09**	**5.34**	**12.03**	**2,771.5**	**2.05**
L.A - I.R	T3	3.33	4.56	18.00	0.026	0.23	9.80	20.80	353.0	0.23
L.A - M.C	T13	3.40	4.78	15.82	0.028	3.00	9.45	3.50	314.0	0.20
L.A - E.D	T2	3.55	2.56	13.04	0.032	1.96	9.80	24.80	779.0	0.50
L.A - E.D	T12	3.30	6.89	19.73	0.148	4.70	12.25	0.50	177.0	0.11

L.A - E.D	T14	3.59	2.64	24.25	0.019	1.45	11.90	0.10	115.0	0.07
Mean		**3.48**	**4.03**	**19.01**	**0.066**	**2.70**	**11.32**	**8.47**	**357.0**	**0.23**
L.A - E.O	T4	3.64	7.10	8.17	0.063	0.23	3.15	4.90	210.0	0.13
L.A - E.O	T5	2.97	3.69	3.13	0.050	1.41	3.15	30.90	775.0	0.50
Mean		**3.31**	**5.40**	**5.65**	**0.057**	**0.82**	**3.15**	**17.90**	**492.5**	**0.32**
E.O	T15	3.33	2.68	9.82	0.048	1.59	10.50	3.40	263.0	0.17
E.O	T16	3.57	6.70	28.27	0.040	3.01	12.95	2.30	358.0	0.23
Mean		**3.45**	**4.69**	**19.05**	**0.044**	**2.30**	**11.73**	**2.85**	**310.5**	**0.20**
E.D	T1	5.76	2.07	12.26	0.019	0.93	2.80	25.40	766.0	0.49
E.D	T11	3.20	2.35	28.53	0.030	5.45	3.50	17.30	524.0	0.34
Mean		**4.48**	**2.21**	**20.40**	**0.025**	**3.19**	**3.15**	**21.35**	**645.0**	**0.42**
R.F	T6	3.60	8.48	23.47	0.082	1.53	6.65	12.50	373.0	0.24

Notes: L.A: Lepironia articulata; E.D: Eleocharis dulcis; M.C: Melaleuca cajuputi; I.R: Ischaemum rugosum; E.D: Eleocharis dulcis; E.O: Eleocharis ochrostachys; R.F: Rice field

Total nitrogen at study sites ranged from 3.15 - 11.73 mg/L (Table 1). The highest TN was found in the *Eleocharis ochrostachys* habitat (11.73 mg/L) and the lowest ones were found at the *Lepironia articulata - Eleocharis ochrostachys* habitat (3.15 mg/L) and *Eleocharis dulcis* habitat (3.15 mg/L). In general, TN was not high and was different between the habitats. TP was low in the habitats at PMSHCA, ranging from 0.025 to 0.082 mg/L (Table 1). The highest TP was found in rice fields (0.082 mg/L) and the lowest TP was found at *Eleocharis ochrostachys* habitat (0.025 mg/L). The high TP value was usually resulted from the use of fertilizers for agricultural activities. In canals, the average TP was 0.056 mg/L.

The concentration of Al^{3+} in water at the habitats at PMSHCA ranged from 2.85 to 21.35 mg/L. The highest Al^{3+} value was found at *Eleocharis dulcis* habitat (21.35 mg/L) and the lowest Al^{3+} value was found at *Eleocharis ochrostachys* habitat (2.85 mg/L). The concentration of Fe^{2+} at the habitats ranged from 0.23 to 3.19 mg/L. The highest Fe^{2+} value was found at *Eleocharis dulcis* habitat (3.19 mg/L) and the lowest Fe^{2+} value was found at *Lepironia articulata - Ischaemum rugosum* habitat (0.23 mg/L). The concentration of Fe^{2+} at the canals was low (1.09 mg/L). Results from this study showed that the concentration of Al^{3+} may pose certain risk to biodiversity at the conservation area while Fe^{2+} concentration may not cause any harm.

3.2. Soil quality

The results of soil analysis were presented in Table 2. Soil pH values at study sites ranged from 3.03 to 3.74. Soil pH values of this study were consistent with findings of Ni and Triet (2013) (3.25 - 3.87) but lower than findings of Thia (2007) (3.39 - 4.30). With low pH values, the soil at PMSHCA was classified as very acidic soil (Hoa, 2017) and this could potentially release Al^{3+}, Fe^{2+} which affects organisms in the conservation area. EC in the soil ranged from 0.255-3.798 mS/cm. The highest EC value was found at *Lepironia articulata - Eleocharis dulcis* habitat (3.798 mS/cm) and the lowest EC value was found in the rice field habitat (0.255 mS/cm). Study of Ni and Triet (2013) reported that EC ranged from 0.116 to 1.890 mS/cm, lower than that found in this study. In acid sulphate soils, high EC due to the presence of H^+, Fe^{2+}, Al^{3+} ions (Hoa, 2017). Salinity of soil in the habitats of PMSHCA ranged from 0.16 to 2.43‰. The highest salinity was

found at *Lepironia articulata - Eleocharis dulcis* habitat (2.43‰) due to saline intrusion from the canal systems. This result was consistent with EC measurements as mentioned previously. Thus, the area is at risk of saline intrusion.

The organic matter in soil ranged from 8.06 to 63.33%, classified medium to very high organic level (Hoa, 2017). The concentrations of organic matter in soil was from high to very high at *Lepironia articulata - Eleocharis dulcis* habitat (28.88%), *Lepironia articulata - Melaleuca cajuputi* habitat (63.33%), *Lepironia articulata - Ischaemum rugosum* habitat (39%), *Eleocharis dulcis* habitat (24.97%) and medium at habitats of *Lepironia articulata - Eleocharis ochrostachys, Eleocharis ochrostachys* and rice field. At Tram Chim National Park, organic matters were also high, ranging from 10 to 30% (Sum, 2015). Compared with study of Thia (2007) at the same place (OM was 9.63 - 34.39%), there is currently accumulation of organic matter the conservation area.

Total acidity ranged from 16.13 - 34.72 meq H^+/100g soil. The highest total acidity was found at *Lepironia articulata - Eleocharis dulcis* habitat (34.72 meq H^+/100g soil) and the lowest total acidity was found at the rice field habitat (16.13 meq H^+/100g soil). Total acidity comprises soluble H^+ ions, exchangeable H^+ and H^+ decomposed from dissolved aluminum forms, exchanged aluminum and aluminum hydroxyl in soil. In the Vietnamese Mekong Delta, total acidity comprises of Al^{3+} and H^+ in which Al^{3+} largely contributes to the acidity in the acid sulfate soil (Hoa, 2017). Study of Ni and Triet (2013) in the same area showed that total acidity in soil ranged from 0.125 - 8.208 meq H^+/100g soil which was much lower than the result of this study. The exchangeable Al^{3+} values ranged from 13.31 to 27.56 meq/100g soil at the habitats. The highest Al^{3+} concentration was found at *Lepironia articulata - Melaleuca cajuputi* habitat (27.56 meq/100g soil) and the lowest Al^{3+} concentration was found in *Lepironia articulata - Eleocharis ochrostachys* habitat (13.31 meq/100g soil). The value of exchangeable Al^{3+} in the current study was higher than the previous studies which were 1.125 to 22.00 meq/100g (Ni and Triet, 2013) and 9.88 - 15.83 meq/100g (Thia, 2007). Comparing the amount of exchangeable Al^{3+} in PMSHCA in this study to that of Tram Chim National Park where exchangeable Al^{3+} was found ranging from 10.1 to 20 meq/100g (Sum, 2015), exchangeable Al^{3+} in the soil in PMSHCA was higher. The exchangeable aluminum is rated at a high level when its values fall in the range of 10.1 - 20.0 meq Al^{3+}/100g (Hung, 2009). The high exchangeable aluminum in soil leads to low pH, it forms acidity of soil, releasing heavy metals affecting biodiversity in the conservation area (Hung, 2009).

Table 2. Soil quality at the Phu My Species and Habitat Conservation Area

Habitats	Site	TP	TN	CHC	K	P_2O_5	pH	EC	S	Acidity	Al^{3+}
		%	%	%	meq/100g	mgP/100g		mS/cm	‰	meq H^+/100g	meq Al^{3+}/100g
L.A-E.D	M2	0.027	0.351	32.2	0.163	1.5	3.55	7812.0	5.00	37.7	9.9
L.A-E.D	M9	0.012	0.085	42.5	0.139	1.6	3.02	3443.0	2.20	50.8	35.3
L.A-E.D	M7	0.014	0.030	11.9	0.127	13.6	3.77	151.0	0.10	15.7	13.3
Mean		**0.018**	**0.155**	**28.9**	**0.143**	**5.5**	**3.45**	**3802.0**	**2.43**	**34.7**	**19.5**
L.A - M.C	M8	0.025	0.131	63.3	0.170	13.1	3.35	804.0	0.50	32.1	27.6
L.A - I.R	M5	0.024	0.365	40.5	0.112	12.3	3.52	1196.0	0.80	26.8	23.9
L.A - I.R	M13	0.018	0.086	37.5	0.136	1.8	2.95	2324.0	1.50	41.3	24.6
Mean		**0.021**	**0.226**	**39.0**	**0.124**	**7.1**	**3.24**	**1760.0**	**1.15**	**34.1**	**24.3**

L.A - E.O	M1	0.019	0.110	7.6	0.087	2.2	3.43	449.0	0.30	16.3	13.9
L.A - E.O	M11	0.020	0.037	9.9	0.134	3.3	3.42	394.0	0.30	17.6	12.8
Mean		**0.020**	**0.074**	**8.7**	**0.111**	**2.8**	**3.43**	**421.5**	**0.30**	**17.0**	**13.4**
E.D	M4	0.019	0.252	36.3	0.109	6.5	3.22	1086.0	0.70	27.5	22.3
E.D	M10	0.015	0.039	13.6	0.032	5.8	2.83	2012.0	1.30	33.4	22.1
Mean		**0.017**	**0.146**	**25.0**	**0.071**	**6.2**	**3.03**	**1549.0**	**1.00**	**30.5**	**22.2**
E.O	M6	0.011	0.019	5.5	0.077	12.1	3.20	685.0	0.40	12.0	11.6
E.O	M12	0.015	0.044	19.7	0.139	8.0	3.12	915.0	0.60	26.6	22.2
Mean		**0.013**	**0.032**	**12.6**	**0.108**	**10.1**	**3.16**	**800.0**	**0.50**	**19.3**	**16.9**
R.F	M3	0.020	0.097	8.1	0.155	5.5	3.74	255.0	0.20	16.1	13.9

Notes: L.A: Lepironia articulata; E.D: Eleocharis dulcis; M.C: Melaleuca cajuputi; I.R: Ischaemum rugosum; E.D: Eleocharis dulcis; E.O: Eleocharis ochrostachys; R.F: Rice field

Total phosphorus concentration in soil at the habitats of PMSHCA were from 0.013 to 0.025%. The highest TP was found at *Lepironia articulata - Melaleuca cajuputi* habitat (0.025%) and the lowest TP was found at *Lepironia articulata - Eleocharis ochrostachys* habitat and Rice field habitat (0.013%). This result showed that soil of PMSHCA is in the poor of phosphorus (Can, 1978). TP value in PMSHCA soil was lower than that of Tram Chim National Park (in the medium range of 0.04 - 0.1%) (Sum, 2015). The available phosphorus in the habitats of PMSHCA ranges from 5,53 to 13.10 mgP/100g soil, in which the habitat of *Lepironia articulata - Melaleuca cajuputi* reached the highest value (13.54 mgP/100g soil) and the lowest one was found at the *Lepironia articulata - Eleocharis ochrostachys* habitat (2.76 mgP/100g soil). The concentration of mobile phosphorus in soil of all habitats was from very poor to moderate.

Total nitrogen in soil of the habitats ranged from 0.03% - 0.23%, which is from poor to rich (Hung, 2009). High TN values were found in the *Lepironia articulata - Ischaemum rugosum* habitat and *Lepironia articulata - Eleocharis dulcis* habitat, medium TN levels were found at *Lepironia articulata - Melaleuca cajuputi* habitat and *Lepironia articulata - Eleocharis dulcis* habitat and the low TN concentrations were found at *Lepironia articulata - Eleocharis ochrostachys* habitat, *Eleocharis ochrostachys* habitat, and rice field habitat. TN concentrations in PMSHCA soil were generally higher than those of Tram Chim National Park (0.15 - 0.1%) (Sum, 2015).

The amount of exchangeable potassium (K_2O) in soil at the habitats of PMSHCA was very low to medium, ranging from 0.09 - 0.17 meq/100g soil. The concentration of potassium exchanged in soil at *Lepironia articulata - Melaleuca cajuputi* habitat (0.17 meq/100g soil) and rice field habitat (0.16 meq/100g soil) were at medium level and the remaining habitats were in low level. In the Mekong Delta, the concentration of exchangeable potassium in the surface layer of acid sulphate soil ranges from 0.2 to 0.4 meq/100g soil (Hoa, 2017). Potassium is needed for growth and development of *Eleocharis ochrostachys*, especially in the process of generating water chestnut that is considered as food for crane. Potassium in rice field soil was low which is not suitable for rice cultivation.

4. Conclusion

Water temperature at PMSHCA was suitable for the growth of organisms. Water has a relatively low pH, high conductivity, and high Al^{3+}. TN was high but TP was low. COD was not

high. Water quality at PMSHCA was found to show low phosphorus, saline intrusion risk, heavy metals released by acidic conditions and this could affect growth and development of aquatic animals as well as biodiversity of the conservation area.

Soil in the study area was low pH and high Al^{3+}. TN was from poor to rich, TP from poor to moderate, and K_2O was from poor to moderate. OM was from medium to very rich. Soils at canals' banks were at risk of salinity. The concentration of nutrients were uneven distribution among the habitats, leading to different distribution of vegetation. The discharge and velocity flow varied between the locations because water depth in canals were different. Poor water exchange in the conservation area and human activities could lead to water pollution. Natural and anthropogenic activites could affect physical and chemical properties of soil, water and biodiversity in the conservation area, thus regularly monitor environmental compartments is urgently needed to meet sustainable development goal in the area.

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