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# Aquatic environmental characteristic of Singkil Swamp Wildlife Reserve in Aceh Singkil Regency

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ABSTRACT

Singkil Swamp Wildlife Reserve is a peat swamp ecosystem located in Aceh Singkil Regency, Aceh Province. Peat swamp ecosystem has an important function in protecting and balancing water systems, carbon stocks and biodiversity conservation. However, information on the characteristics of the waters of this ecosystem is still not widely known, especially in the area of utilization that is influenced by community activities. This study aims to determine the aquatic environmental characteristics of the Singkil Swamp Wildlife Reserve utilization area covering the physical and chemical parameters of the water and the relationship among those parameters. Sampling was carried out through field observations both in-situ and ex-situ at 5 stations for 3 months (April-June 2021). Observations were made on water quality parameters namely temperature, transparency, depth, current, colour, salinity, water smell, pH, DO, TDS, TSS, conductivity, phosphate and nitrate. Analysis of the data was conducted, namely correlation analysis, PCA (Principal Component Analysis) and CA (Cluster Analysis). The water color was black and the pH was acidic, that is a characteristic of the swamp waters. The results of the measurement of water quality parameters indicate that TDS (13-44 mg/l), TSS (9-236 mg/l), total phosphate (0.01-2.14 mg/l), and nitrate (0.5-25.7 mg/l) were suitable for freshwater aquaculture to support fishery reserve. Based on the clustering of those stations, 5 observation stations were grouped into two different groups, namely cluster 1 with the number of observation stations of 2 stations (Stations 1 and 2) and cluster 2 with the number of observation stations of 3 stations (3, 4 and 5). The parameter values of total phosphate, pH, DO, and nitrate in cluster 1 tend were higher than in cluster 2.

## Introduction

Indonesia has 14.9 million ha of peatland area, where 7.2 million ha of the peatland area is distributed in Sumatra island (Wahyunto *et al*., 2014). One of the peatlands located in the Sumatra region is the Singkil Swamp Wildlife Reserve (SSWR). SSWR is an area with important biodiversity values in the Alas watershed of Aceh Singkil district, Aceh Province (Ariantiningsih, 2007). The Singkil Swamp forest area is part of the Leuser Forest Ecosystem. Singkil Swamp Wildlife Reserve conservation area is the only wildlife reserve in Aceh Province. The rules and legal basis for the status of the SSWR area have undergone several changes. Initially, Rawa Singkil was designated as a Natural Sanctuary Area in 1998 called Rawa Singkil Wildlife Reserve based on the Decree of the Minister of Forestry No.166/Kpts-II/1998 with an area of ±102500 hectares. SSWR has currently an area of 81802.22 hectares based on the Decree of the Minister of Environment and Forestry Number:SK.859/MENLHK/SETJEN/PLA/2/11/2016 (Aceh Natural Resources Conservation Center, 2018).

As a component of wetlands, peat swamp forests have unique characteristics and essential functions in forest and fishery products (Haryono, 2012). The Peat Ecosystem has the primary function of protecting and balancing water systems, storing carbon stocks, and preserving biodiversity to preserve the functions of the Peat Ecosystem

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(Indonesian Minister of Environment Regulation, 2019). Peatland is an ecosystem classified as marginal and fragile land with low productivity and prone to damage (Napitupulu and Mudiantoro, 2016). Singkil Swamp is crucial for the productivity of coastal fisheries in the western part of Aceh (Onrizal, 2019). For managing SSWR, on January 16, 2018, based on the Decree of the Director-General of Conservation of Ecosystem of Natural Resources Number: SK.7/KSDAE/SET/KSA.0/1/2018, established the Singkil Swamp Wildlife Reserve Management Block. Based on the decree, SSWR is divided into five management blocks, namely Protection Block (65908.61 ha/80.51%), Utilization Block (4666.44 ha/5.7%), Special Block (10074.82 ha/12.32%), Rehabilitation Block (1073.97 ha/1.38%), and Religious, Cultural and Historical Block (78.38 ha/0.1%) (Aceh Natural Resources Conservation Center, 2018).

The utilization block of Singkil Swamp Wildlife Reserve (SSWR) is located in the south of the SSWR area. This area is in the form of a riparian forest, where the river area is Lae Treup, used by the surrounding community for fishing and tourism activities. Although the Singkil Swamp Wildlife Reserve has a vital role in the sustainability of biodiversity and meeting the surrounding community's needs. Research related to the characteristics of the aquatic environment in the Singkil Swamp Wildlife Reserve is still not widely known. The characteristics of peat water can change and differ based on the conditions where the peat water is located, so it is important to characterize peat water in various places (A'idah *et al.*, 2018). Until now, studies that have been carried out in the Singkil Swamp Wildlife Reserve include the taxonomical study of Pandanus (Pandanaceae) (Marpaung *et al.*, 2013), understorey diversity (Understorey) (Onrizal, 2019), identification of tree species nesting places for Sumatran orangutans (*Pongo abelii*) (Sabtono, 2019), primate diversity (Maulizar, 2019), study of existing conditions in Singkil Swamp Peat Wildlife Sanctuary (Wali *et al.*, 2020), vegetation analysis (Sugianto et al., 2021) and Sumatran orangutan habitat preferences (*Pongo abelii*) (Yunus, 2019).

Information related to the characteristics of the aquatic environment through the study of water physical-chemical parameters is essential for developing the potential of the Singkil Swamp Wildlife Reserve, one of which is in the fisheries aspect. The physical-chemical characteristics of water as a reference for water quality are often used to measure water conditions relative to the needs of biotic species and human needs (Sule *et al.*, 2018). The study aims to determine the physical-chemical characteristics of the waters of the Singkil Swamp Wildlife Reserve and recommendations for its use to support fisheries reserves..

## Materials and Methods

### Location and time

The research was conducted in Singkil Swamp Wildlife Reserve utilization area, Lae Treup River and Alas-Singkil River, Aceh Singkil Regency (Aceh Province) (Table 1 and Figure 1). Data collection was carried out at five stations from April to June 2021 (3 months). Determination of stations was based on purposive sampling method, namely the determination of station points based on the utilization block, the flow of boat traffic, and the location of fishing ground.

The tools used for measurement of water physics-chemical parameters consisted of digital pH meter Atago DPH-2 (for pH measurement), refractometer Atago master 20T (for salinity), dissolved oxygen meter Lutron DO-5510 (for dissolved oxygen and temperature), TDS/EC meter HM digital (for TDS and conductivity), Geopacks flowmeter (advanced) ZMFP126-S for current, Secchi disk (for water transparency), scale boards for depth, Garmin GPS Montana 680 (for station coordinate point retrieval), 500 ml sample bottles for water sample containers, marina cooler box 35s (for storing water sample bottles), stationery for recording data, sense of smell for smell, sense of sight to see color, and spectrophotometer nova 60 for measurement of nitrate and total posfat. The materials used in the study were water samples of the Singkil swamp wildlife refuge and $H_2SO_4$ to preserve water samples.

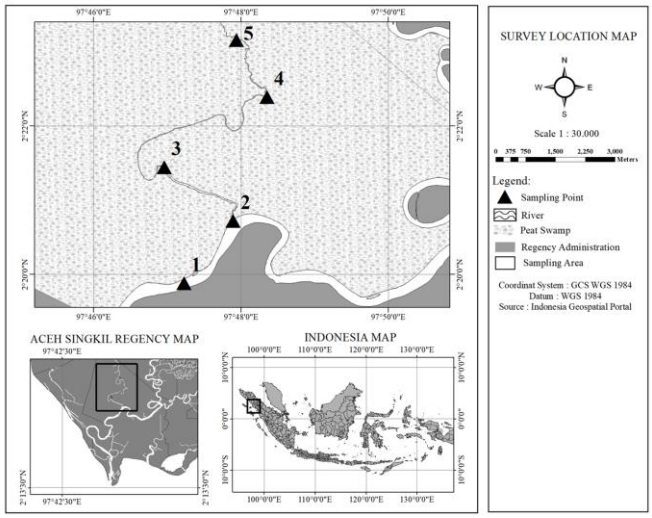


Figure 1. Survey location map.

Table 1. Position of five data collection points.

| Stations | Positions | Characteristic |
|---|---|---|
| Station 1 | 2,333244° N and 97,819718° E | Located in the Alas-Singkil Watershed, near the settlement (± 300 m) and is prone to be affected by community activities (fishing, gardening, domestic waste disposal, and tourism). |
| Station 2 | 2,346328° N and 97,801423° E | In the meeting area between the Alas-Singkil River with Lae Treup and mixing watershed with peat swamp water. |
| Station 3 | 2,358850° N and 97,780228° E | Located on the Lae-Treup Stream, the community uses the area for fisheries and tourism activities and is surrounded by vegetation (*Hanguana malayana*). |
| Station 4 | 2,376109° N and 97,803596° E | Located on the Lae-Treup Stream, the community uses the area for fisheries and tourism activities and is surrounded by vegetation (*Hanguana malayana*). |
| Station 5 | 2,459313° N and 97,773211° E | In the Lae-Treup Stream, the community uses the area for fisheries and tourism activities and is surrounded by vegetation (*Hanguana malayana*). The deeper into the forest of the Singkil Swamp Wildlife Refuge, the body of water traversed by the boat is getting smaller as increasingly dense vegetation covers the road. |

Table 2. Measurement of water physical chemical parameters at each station.

| Parameter | Station | | | | | Water Quality Standards (Class I, II, III and IV) |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | |
| Temperature ($^0$C) | 26.3-30.0 (27.56±2.11) | 26.1-29.0 (27.1±1.64) | 25.6-26.4 (26.03±0.4) | 26.6-27.2 (26.86±0.3) | 26.7-27.2 (27±0.26) | Dev 3* for all classes |
| Transparency (cm) | 13.0-30.0 (22.67±8.74) | 30.0-42.5 (36.67±6.29) | 92.5-102.5 (99.16±5.77) | 97.5-117.5 (105±10.89) | 82.5-145 (122.5±34.73) | - |
| Depth (m) | 1.0-15.0 (1.25±0.25) | 2.5-4.5 (3.5±1) | 1.5-2.5 (1.9±0.53) | 0.8-4 (2.76±1.72) | 4-5 (4.33±0.57) | - |
| Current (m/s) | 0.12-0.14 (0.12±0.01) | 0.06-0.21 (0.11±0.08) | 0.13-0.19 (0.15±0.03) | 0.15-0.19 (0.17±0.02) | 0.08-0.24 (0.16±0.08) | - |
| pH | 5.5-6.2 (5.87±0.35) | 4.7-6.5 (5.57±0.9) | 4-4.4 (4.23±0.21) | 3.9-4.4 (4.07±0.29) | 3.9-4.3 (4.07±0.21) | - |
| DO (mg/l) | 2.2-3.9 (2.76±0.98) | 1.2-1.6 (1.43±0.21) | 1.1-1.4 (1.27±0.15) | 1-1.3 (1.1±0.17) | 1.1-1.3 (1.23±0.11) | 6,4,3,1* |
| Salinity (ppt) | 0 | 0 | 0 | 0 | 0 | - |
| TDS (mg/l) | 18-36 (26.33±9.07) | 13-44 (24±17.35) | 21-22 (21.33±0.58) | 17-18 (17.67±0.57) | 20-22 (21±1) | 1000,1000, 1000,2000* |
| TSS (mg/l) | 20-94 (47.67±40.38) | 10-214 (78.33±117.49) | 9-236 (85.33±130.48) | 12-200 (74.67±108.54) | 13-194 (74.33±103.64) | 40,50 100,400* |
| Conductivity (S/m) | 36.0-71.0 (52.33±17.62) | 26.0-88.0 (48±34.69) | 42.0-43.0 (42.33±0.58) | 34.0-36.0 (34.67±1.15) | 40.0-44.0 (42±2) | - |
| Total Phosphate (mg/l) | 0.06-2.14 (0.79±1.17) | 0.04-0.24 (0.12±0.1) | 0.02-0.05 (0.03±0.02) | 0.01-0.09 (0.05±0.04) | 0.03-0.17 (0.08±0.07) | 0.2,0.2,1,-* |
| Nitrate (mg/l) | 0.5-19.5 (9.17±9.61) | 0.5-25.7 (10.47±13.4) | 0.5-17.2 (6.53±9.26) | 0.5-21 (7.87±11.4) | 0.5-24.6 (9.33±13.27) | 10,10,20,20* |
| Smell | No smell | No smell | No smell | No smell | No smell | - |
| Colour | Brown | Dark brown | Black | Black | Black | - |

*Water quality standards in Government Regulation of the Republic of Indonesia number 22 of 2021.

Temperature, salinity, DO, pH, current, transparency, depth, smell, colour, conductivity and TDS were measured on the water surface in-situ. Water samples were taken as much as 500 ml

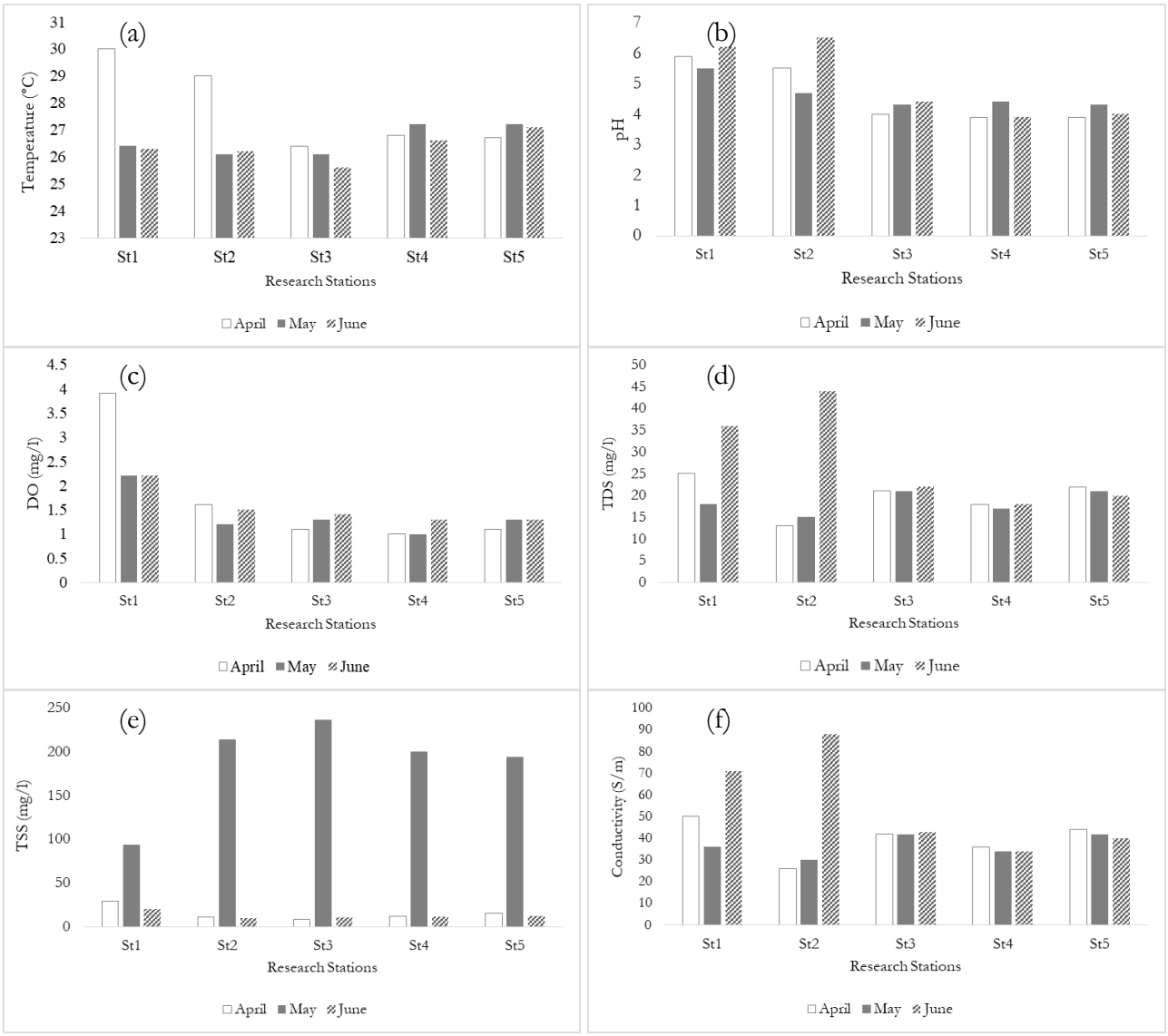
(without preservatives) for TSS and 1000 ml sample for nitrate and total phosphate (with preservative $H_2SO_4$) and then stored at 4°C. Measurement of physical and chemical parameters of the waters followed APHA (2017). Ex-situ water sample analysis was carried out at Laboratory of The Center for Environmental Health Engineering and Disease Control, Medan city.

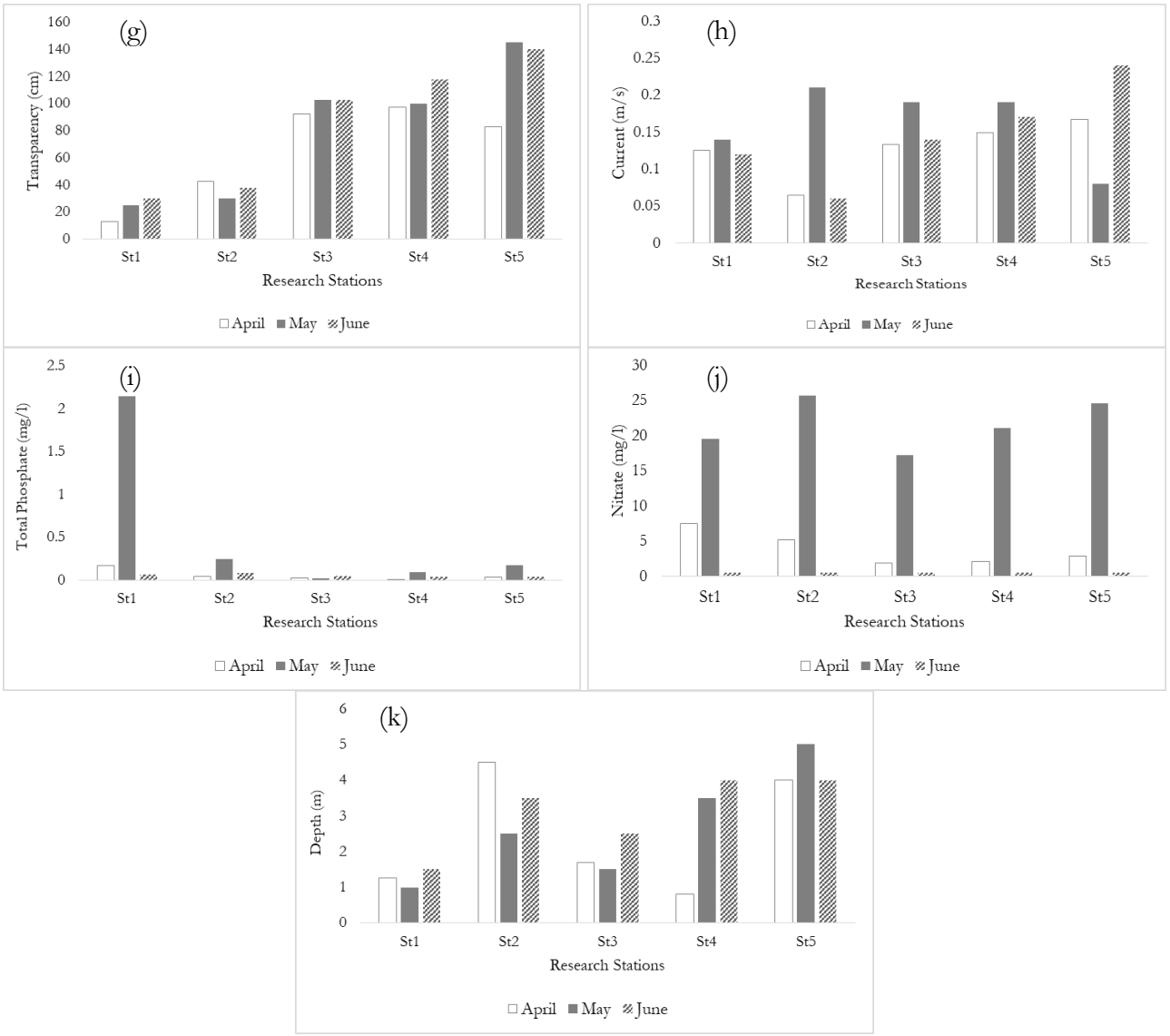
## Data analysis

The data analysis used in this research consisted of correlation analysis, principal component analysis (PCA) and Cluster Analysis (CA) using Microsoft Excel, PAST 4.03 (Paleotogical Statistics) and R Studio 4.1.2 software. PCA analysis is a multivariate analysis method that aims to group variables whose linear correlations are linear into one main component. (Muttaqin, 2017). CA is a multivariate analysis commonly used to group objects based on the distance or similarity of characteristics of objects to be grouped (Radiarta et al., 2013). The water physic-chemical data obtained was compared with the national water quality standards in Government Regulation of the Republic of Indonesia number 22 of 2021 to obtain recommendations for the management and utilization of the waters of the Singkil Swamp Wildlife Reserve.

## Results

The measurement of the physical-chemical parameters of water in the Singkil Swamp Wildlife Reserve during the study (April-June) can be seen in Figure 2 and Table 2. Characteristics of the aquatic physical-chemical parameters obtained during the study were temperature (25.6-300C), transparency (13-145 cm), depth (0.8-5), current (0.06-0.24), no smell, brown to black water colors, pH (3.9-6.5), DO (1-3.9 mg/l), salinity (0 ppt), TDS (13-44 m/l), TSS (9-236 mg/l), conductivity (26-88 S/m), total phosphate (0.01-2.14 mg/l) and nitrate (0.5-25.7 mg/l).






Fiure 2. Dinamics of physical-chemical parameters of waters (a) temperature, (b) pH, (c) DO, (d) TDS, (e) TSS, (f) Conductivity, (g) Transparency, ( h) Current, (i) Total Phosphate, (j) Nitrate, k (Depth).

The results of the analysis of the main components show that the contribution of the two main components to the total variety reached 87.81% of the total variety. The eigenvalue values of the two main components are 7.41 and 1.36 respectively with variety percentages of 74.19% and 13.61% respectively. The two main components with a variety of 87.81% of the total diversity indicate that the two main components adequately explain the variation in the data. While PCA analysis and correlation between aquatic parameters are presented in Figure 3 and Table 3.

Cluster Analysis (CA) was applied to the water quality conditions in SMRS to see the similarities of each observation station throughout the research site. The result of CA in the form of a dendogram (Figure 4) that has grouped 5 water observation stations into two different groups, namely cluster 1 with the number of observation stations as many as 2 stations (1 and 2) and cluster 2 with the number of observation stations as many as 3 stations (3, 4 and 5).

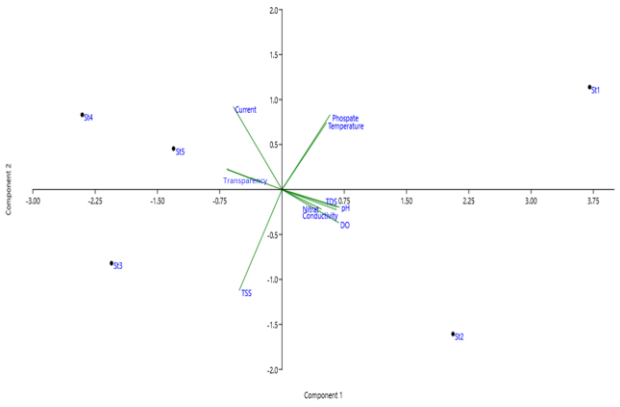



Figure 3. PCA biplot ordinance between water physical-chemical parameters by stations.

Table 3. Correlation Between Physical-Chemical Parameters of Water

| | Temperature | Trans parency | Current | pH | DO | TDS | TSS | Conduc tivity | Total Phospate | Nitrate | Depth |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Temperature** | 1 | | | | | | | | | | |
| **Transparency** | -0.60 | 1 | | | | | | | | | |
| **Current** | -0.46 | 0.90 | 1 | | | | | | | | |
| **pH** | 0.66 | -0.99 | -0.92 | 1 | | | | | | | |
| **DO** | 0.65 | -0.97 | -0.96 | 0.99 | 1 | | | | | | |
| **TDS** | 0.53 | -0.85 | -0.84 | 0.90 | 0.89 | 1 | | | | | |
| **TSS** | -0.82 | 0.60 | 0.28 | -0.64 | -0.55 | -0.61 | 1 | | | | |
| **Conductivity** | 0.53 | -0.84 | -0.84 | 0.90 | 0.89 | 1.00 | -0.60 | 1 | | | |
| **Total Phospate** | 0.71 | -0.73 | -0.44 | 0.76 | 0.67 | 0.77 | -0.96 | 0.76 | 1 | | |
| **Nitrate** | 0.78 | -0.52 | -0.66 | 0.60 | 0.69 | 0.50 | -0.34 | 0.52 | 0.28 | 1 | |
| **Depth** | 0.02 | 0.48 | 0.16 | -0.40 | -0.27 | -0.38 | 0.48 | -0.35 | -0.62 | 0.47 | 1 |

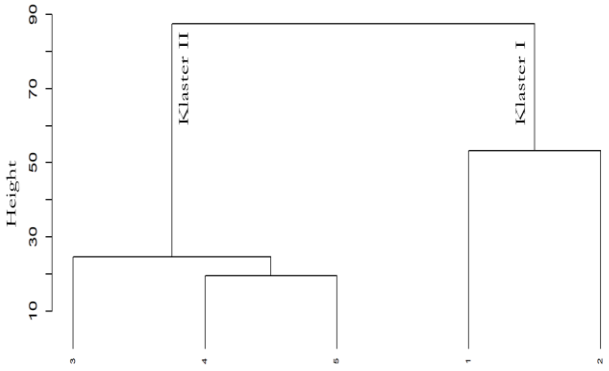



Figure 4. Dendogram of aquatic areas grouping based on water quality conditions

## Discussion

The Singkil Swamp Wildlife Reserve (SSWR) is a riparian forest used by local people for fishing and limited tourism. The Singkil Swamp Wildlife Reserve has pH value of 3.9-6.5 (Table 2). This value indicates that the water is acidic. The acidic nature of the waters is a distinctive characteristic of peatland waters. Similar results were found in other peatland waters in Indonesia, such as the pH of the Bangkau Swamp Waters of 5.51-6.57 (Yunita, 2012), Tungkal Ilir Waters 2.35-3.67 (Said *et al.*, 2019), Pontianak Waters (4-5.7) (A'idah *et al.*, 2018), and the waters of the Bukit Batu Biosphere Reserve 3.7-3.8 (Fahmi *et al.*, 2015). pH value decreases as $CO_2$ concentrations increase due to microbial activity in decomposing organic matter in peatlands (Sinaga *et al.*, 2016). The water colour, brown to black is a characteristic of peat waters found in the Singkil Swamp Wildlife Reserve (Table 2). Organic plant materials that turn into peat cause peat waters to turn brown to dark black and have a low pH value (Said *et al.*, 2019).

The content of dissolved oxygen (DO) in the Singkil Swamp Wildlife Reserve waters is around 1-3.9 mg/l (Table 2). This value is categorized as low compared to the optimal dissolved oxygen requirement for fish in general, ranging 4-8 mg/l (Augusta and Pernando, 2019). The DO value in peat waters is positively correlated with pH value. This is indicated by the correlation value of 0.99 (Table 3) and the direction of the PCA biplot in the same direction (Figure 3).

Figure 3 shows that the main correlated components at Station 1 are total phosphate and temperature (r=0.71). The highest phosphate content was found at Station 1 with an average measurement value for three months, namely 0.79 mg/l (Table 2) and the highest one was in May (2.14 mg/l) (Figure 2). The high phosphate value is in Station 1, the station is in the closest location to the residential community of Teluk Rumbiah Village (±300 m). Chemical parameters that interfere with the quality of the waters are nitrates and phosphates that can be found in household fertilizers and wastes and have the potential to flow to nearby water sources such as groundwater, rivers and larger bodies of water (Patricia *et al.*, 2018). Phosphorus is widely used as fertilizer, soap or detergent, ceramic industry material, lubricating oil, food and beverage products, and catalysts that if it accumulates into waste by bathing, washing, and disposing of domestic waste from residential areas, which cause high phosphate values (Yulistia, 2020).

At station 2 the main components consist of TDS, pH, nitrate, Conductivity and DO (Figure 3). Station 2 is the meeting point between the Alas-Singkil River and Lae-Treup, where at this station, there is a dynamic of water entry from the Alas-Singkil River to Lae-Treup or vice versa. In addition,

the high nitrate value at Station 2 is a result of palm oil planting activities carried out by the community. Population waste is a source of water pollutants containing many nitrogen and phosphate nutrients (Brahmana and Achmad, 2012). One of the waste that has the potential to increase nitrate concentration in the water column is the utilization of fertilizers in agricultural land (Putri *et al*., 2019).

At Stations 3, 4, and 5 were found Bakung (*Hanguana malayana*) that grow to dominate the riverbank. The more entering the forest area of Singkil Swamp Wildlife Refuge, the river body is getting narrower due to increasingly dense daffodils. TSS is the only main component at Station 3 (Figure 3). The highest TSS average value was also obtained at Station 3 (Table 2). High TSS content can cause a decrease in water quality so that it is not worth consuming. The higher the content of TSS in water, the water will contain clumps of microparticles that have not previously been clumped (Said *et al*., 2019). While at Stations 4 and 5, the main correlated components were current and water transparency, with a value of r=0.9 (Table 3). In addition, Table 3 also shows that transparency is positively correlated with depth (r = 0.48). This means that the deeper the waters, the transparency will increase. The range of correlation coefficient values is -1 to 1 ($-1 \leq r \geq 1$), where if the value of r is close to 1 or -1, it indicates that the relationship between the two parameters is getting closer, while the value of r that is close to 0 indicates that there is no close relationship between the two parameters (Walpole, 1997).

The dynamics of water's physical-chemical parameters can be affected by rainfall. In May, there was an increase in the value of nitrates and TSS. Unlike April and June, when measurements and sampling in the field conducted in May occur raining. In addition, based on climatology data obtained from the Ministry of Public Works and Public Housing, Sianjo-Anjo Station, Aceh Singkil Regency, between April, May, and June, the highest total rainfall value occurred in May (425.2 mm), followed by June (194.7 mm) and April (153.2 mm).

Figure 4 shows the stations in the study are divided into two clusters. These two clusters can be seen in the physical-chemical parameters of waters, especially colour, total phosphate, pH, DO and nitrate. In Cluster 1, the colour of the waters is brown, while in Cluster 2, the water surface is black. The parameter values of total phosphate, pH, DO, and nitrate in Cluster 1 tend to be higher than in Cluster 2. The distribution of research stations into two clusters can also be seen from the region's scope. Cluster 1 area is still dominated by the influence of the flow of the Alas-Singkil River. In comparison, the Cluster 2 area is the flow of the Lae Treup River, which is covered by peatland forests and is overgrown with vegetation.

Local and outside communities use the utilization area of Singkil Swamp Wildlife Reserve for fishing and tourism activities. Utilization of resources without being accompanied by good management will threaten the sustainability of resources. Parameter values of DO, TDS, TSS, phosphate and nitrate at each station in the waters of the Singkil Swamp Wildlife Reserve (SSWR) are 1-3.9 mg/l, 13-44 mg/l, 9-236 mg/l, 0.01-2.14 mg/l and 0.5-25.7 mg/l (Figure 2). This value shows that the water quality in Singkil Swamp Wildlife Reserve is in the third grade and can be used for freshwater fish cultivation based on national water quality standards in Government Regulation of the Republic of Indonesia number 22 of 2021. In the national water quality standards in Government Regulation of the Republic of Indonesia number 22 of 2021, water quality is divided into 4 classes. The first class can be used for drinking water, the second class can be used for recreational means of water, freshwater fish cultivation, livestock and water to irrigate crops, the third class can be used for freshwater fish cultivation, livestock and water to irrigate crops and the fourth class is used to irrigate crops. If it is compared to other swamp areas such as DO (3.8-7.28 mg/l) and TDS (204.7-410.2 mg/l) in Bangkau Swamp Waters, DO (0.7-4.7 mg/l), TDS (124-1024 mg/l), nitrat (0-10.2 mg/l), and phosphate (0.25-1.5 mg/l) in Bukit Batu Biosphere Reserve and TDS (81.8-567 mg/l) and TSS (7-12 mg/l) in Tungkal Ilir Waters, DO and TDS in SSWR tend to be smaller than in other areas while TSS, phosphates, and nitrates are slightly higher.

One of the strategies that need to be done to develop the potential of the Singkil Swamp Wildlife Reserve utilization area in fisheries to help the economy of the community and fisheries reserves is the cultivation of environmentally friendly fisheries that utilize local fish. Local fish that generally dominate peat waters are fish species that are able to breathe using oxygen from the air (air breathing) such as climbing gourami (*Anabas testudineus*), kissing gourami (*Helostoma temminckii*), siamese gourami (*Trichogaster pectoralis*), giant gourami (*Osphronemus gourami*), common snakehead (*Channa striata*) and indonesian snakehead (*Channa micropeltes*) (Huwoyon and Gustiono, 2013). Fishing activities that the community has carried out since many years ago in the Singkil Swamp Wildlife Reserve utilization area are feared to affect the population of fish resources

in the future so that environmentally friendly aquaculture efforts are needed to help fish resource reserves in the Singkil Swamp Wildlife Reserve.

## Conclusion

The physical-chemical characteristics of the Singkil Swamp Wildlife Reserve covering temperature (25.6-30 $^0$C), water transparency (13-145 cm), depth (0.8-5 m), no smell, colour (brown to black), current (0.06-0.24 m/s), pH (3.9-6.5), DO (1-3.9 mg/l), salinity (0 ppt), TDS (13-44 mg/l), TSS (9-236 mg/l), conductivity (26-88 S/m), total phosphate (0.01-2.14 mg/l) and nitrate (0.5-25.7 mg/l) are suitable for aquatic biota life. Singkil Swamp Wildlife Reserve's utilisation area can be used for traditional freshwater fish farming activities to maintain fishery reserves.

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