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Assessment of Primary Parameters in Sawa Lake and Their Impact on Productivity

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Abstract: Sawa Lake is one unique enclosed water system situated in southwest Iraq. The current study intends to track the change in water level and analyse the reasons and consequences of the shift in the lake's physicochemical qualities and primary productivity. Monthly samples were taken from three study sites from February to July 2021. The study found that air and water temperatures increased and decreased at all sites, which were evaluated during the study period. The mean salinity values ranged from 85.92 to 19.67‰, with the highest value (52.20‰) occurring before the drought in February and the lowest value (19.67‰) occurring after the drought in July. The pH level ranged from 7.57 to 8.77. The current study's nutrient concentration (nitrite, nitrate, and phosphate) was 1.04-19.91, 21.51-251.79, 0.26 - 2.37µg/L, respectively, and there was a reverse correlation between nitrite and nitrate with salinity. The productivity measured by the light and dark bottle method recorded the lowest level (0.25 $mg/m^3/h$) before the drought, and the highest level (3.25 $mg/m^3/h$) was observed after the drought period. Chlorophyll concentration decreased during a drought due to lowered nutrient inputs. These data demonstrate that primary productivity in the lake's waters is relatively low. And, the drought for the lake occurred as a result of a series of reasons that were strongly influenced by human activities. Traditionally, groundwater is extracted for agricultural purposes in this region. Thus, the rate of groundwater flows into the lake decreases, which negatively affects the physical and chemical parameters and thus affects the productivity of the lake. One of the ways of management is to form a national campaign that adopts exceptional measures to meet the challenges related to groundwater by reformulating and developing water systems, in addition to the proposal to reduce the area of the lake basin industrially to one-third, because the water, even if it returns to flood the lake, does not return to the previous quantities. Thus, when the water quality will be good, it will create the appropriate conditions to increase the productivity of the lake.

Key words: Light and dark bottle method, Sawa Lake, chlorophyll-a, physicochemical parameters.

Introduction

Lakes

Natural lakes are stationary bodies of water without any direct interaction with any other water sources, which are flat like the ocean (Hammer, 1986). Lake ecosystems can be formed up of the physical, chemical, and biological features of the water bodies they hold in arid areas (Bhateria and Jain, 2016). Physical, chemical, and biological qualities within the lake ecosystem are constrained. Based on their nutritional status, lakes are classified as low-nutrition, medium-feeding, medium-

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productivity, and nutrients with high productivity due to increased nitrogen and phosphorus concentrations (Vasistha and Gangly, 2020). Salt lakes feed on salt springs or their presence in dry areas with high water evaporation. The salt is concentrated in it (Al-Handal, 1994), which is attributed to the lack of rainfall and increased evaporation by the increase in temperature in the current years due to the global warming process that the whole world is currently experiencing. Many water quality criteria (environmental variables) might alter owing to environmental factors such as climate and global warming; hence salt lakes are an intriguing internal feature that should be included in water quality modeling (Hussain and Abdul, 2019). Even though inland saltwater rivers and lakes are the exact sizes of freshwater rivers and lakes, there have been comparatively few water quality investigations on salt lakes compared to freshwater lakes (Al-Zubaidi et al., 2021).

Biota may be stressed by changes in water quality in both standing and flowing systems (Lake, 2011). A lower-than-normal flow phase that is extraordinary in duration and intensity is known as hydrological drought (Humphreys and Baldwin, 2003). Drought is caused by a lack of regular precipitation, such as rain and/or snow on stream catchments, along with high levels of evapotranspiration during dry seasons, which, in most situations, lowers sea levels. According to earlier studies of lake regions, water levels in individual lakes can have varied responses to drought, with some systems reaching more severely than others (Webster et al., 1996). Drought, caused by low groundwater levels, loss of vegetation, and climate change, pose a significant danger to natural saline aquatic habitats by altering hydrology and salinity, impacting biodiversity. The drought in this research study was caused by several wells (Hussein, 2018) that irrigated the lake's agricultural land, and the low water level was seen in tandem with the irrigation season. Chemical substances (such as sulphate and nitrate) added to water due to human activities can penetrate the water system's slope during drought fracture (Lake, 2011; SohoulandeDjebou, 2017).

The reactions of lakes to drought differed significantly. During the drought, most lakes lost water, with the most significant reaction being a loss of 26.6%, and 41% of lakes saw water levels drop by more than 0.5 m. Seepage lakes had a more robust and variable response than drainage lakes. In reaction to the drought, seepage lakes lost 8.2 times more surface area and water level than drainage lakes (Perales et al., 2020).

Primary Productivity

The interplay between water's physical and chemical characteristics is crucial in the development, distribution, and abundance of the water environment. Primary productivity is a manifestation of life products in a water body or the outcome of photosynthesis, which plays an essential part in ecosystem function and provides chemical and organic energy to diverse aquatic environmental populations (Mishra and Saksena, 1992). Besides this, it may be used to measure water quality and lake production by providing insight into the interactions between the organism and its environment. Physical and chemical research can also aid in the understanding of a water body's structure and function in connection to its population (Toma, 2011).

Droughts are anticipated to indirectly influence primary ecosystem production due to changes in water quality drivers such as salinity, temperature, turbidity, and nutrient inputs. Ciais et al. (2005) stated that the drought produced a decrease in primary productivity, indicating that the decrease in output may be explained by rainfall deficits and severe summer heat, respectively. Lake Saint Lucia suffered from droughts, resulting in high salt levels and fluctuating rates of primary production. The study also discovered strong links between salinity, nutrients, and production rates. Al-Taee (2017) investigated primary productivity in the Bahr Al-Najaf Depression Reservoir in Iraq and discovered that pelagic productivity was highest in the spring and lowest in the fall. According to a statistical study, spring considerably impacts pelagic net primary productivity.

Studies on primary productivity in Iraqi water environments were few except for the marshes in southern Iraq and the Shatt al-Arab. As for the primary productivity study in Lake Sawa, it is considered the first of its kind.

Materials and Methods

Study Site Description

Sawa Lake is about 23 kilometers west of Muthanna Governorate, in Iraq's southwest, between longitudes (44° 59′ 29.00″ and 45° 01′ 46.60″) and latitudes (31° 17′ 43.11″ and 31°19′ 49.80″; Figure 1). The lake is a closed water system with a surface area of approximately 4.7 km^2 (Al-Tememi et al., 2019). The greatest length and breadth of the lake are about (4.74 and 1.77 km), respectively, but the maximum width (1.77 km) is isolated by a gypsum barrier with a total route of 12.5 km (Hasan et al., 2018). The lake is fed by

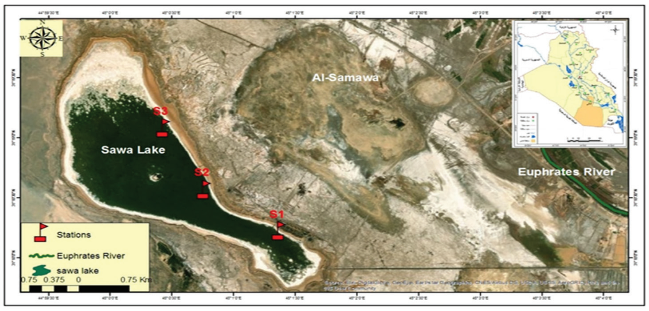

Figure 1: The sites of the study in Sawa Lake.

groundwater from the Euphrates and Dammam aquifers through a system of joints, fissures, and fractures; it is created atop limestone rock and is surrounded by gypsum barriers; and its water chemistry is distinct (Al-Tememi et al., 2019). The lake's bottom has a modest difference in topography, with the western side rising 1 meter higher than the eastern bank (Al-Abadi, 2013).

Sampling Collection

Samples of physical and chemical parameters were conducted from three sites from February 2021 to July 2021, with three duplicates per site. The distance from one site to the other is 2 km. Because of the drying of the lake during the study, the third site determined firstly, was moved to the current site appeared in Figure 3. Water samples for physicochemical analysis were collected using a 5-liter polyethylene bottle pre-washed by the water sample twice before filling. A sample of chlorophyll-a is taken by inserting one liter of water into the vial and then filtering water using filter paper to obtain chlorophyll-a in the laboratory, in addition to using light and dark bottles of Winkler to collect samples to measure the amount of dissolved oxygen (APHA, 2017).

Water Quality Measurement

The physical and chemical parameters studied include air and water temperature (using a mercury thermometer from 0 to 100°C), the concentration of hydrogen ions (using a portable multimeter device), nitrates, nitrite, and phosphates measured according to APHA (2017) and Parson et al. (1984) and the salinity of water according to the following equation (Mackereth et al., 1978):

$$\text{Salinity ‰} = EC \times 640 \times 10^{-6}.$$

Primary Productivity Measurement

Chlorophyll-a (Chll a)

The Millipore apparatus was used to filter 0.5 liters of each sample using GF/C 0.45-micron filter sheets (Parsons et al., 1984). Before concluding the filtering procedure, a few drops of $MgCO_3$ were added and filtered with the remaining material. This was done to prevent the filter paper's pH from becoming acidic, which would cause the chlorophyll to degrade. The filter paper is then folded and stored in a sealed vial in the dark at -20°C until it is analysed in the lab and determined using the acetone extraction technique. The absorbance was determined using a spectrophotometer and the equation below (AHPA, 2017):

$$\textit{Chlorophyll-a} = \textit{Chll a} \times v \,/\, V$$

where

Chll a = 11. 85 D664 – 1. 54 D647 – 0. 08 D630
v = Acetone volume used (mL).
V = Filtered water volume to be extracted (L).
D_{665} = Optical density at wavelengths 664 nm.
D_{645} = Optical density at wavelengths 647 nm.
D_{630} = Optical density at wavelengths 630 nm.

Light and Dark Bottle Method (LDB Method)

The water samples were taken in Winkler bottles (250 ml) from the surface (20-30 cm) as one bottle for light initial and from 1 m deep as one bottle for light and one bottle for dark, and the samples were incubated for 2 hours at each station for three sites. The primary productivity was determined using the light and dark bottles technique. The following equation was used to calculate primary productivity. The following equation was used to calculate productivity (AHPA, 2017):

Net primary productivity = (light bottle DO _ initial bottle DO) / hours.

The result was expressed as mg/m^3/h, as described by Vollenweider (1974).

Results and Discussion

Physicochemical Parameters

Several facets of water's eco-hydrology depend on its physicochemical qualities (Zalewski et al., 1997). Aquatic species' composition, distribution, and abundance are influenced by water's physicochemical qualities (Hinckley et al., 2014).

The temperature is affected not only by the seasons but also by the time of sample collection. During the research period, air and water temperatures changed for all of the sites analysed (19-37.16°C) and (9-26°C), respectively, indicating that temperature variations might be due to meteorological conditions at the time of the study (Figures 2 and 3), primary productivity tended to be high when the air temperature was high (Park et al., 2004). This outcome was consistent with earlier research (Al-Fanharawi, 2013; Ali, 2018).

The lake water was as alkaline as the inland water in Iraq, which verifies the pH values, ranging from 7.57 to 8.77 (Figure 4) over the research period, and may be attributed to the geological formation in the studied region (Al-Tememi et al., 2019; Jaffar, 2017).

Figure 5 depicts the monthly fluctuations in water salinity. The lowest value (17.08) was recorded at site 2 in June, and the highest value (87.97) was measured at site 2 in April; the three sites had a significant correlation (p< 0.05). This has been ascribed to reduced saline groundwater dilution. The cause of this might be Lake drought, which reduces the lake's level and the lake's mean evaporation rates, which have been steadily increasing. The findings suggest that evaporation is not the sole mechanism regulating the salt content in the lake. Literature supported this (Al-Fanharawi, 2013; Al-Tememi et al., 2019) fact that salinity could be the main key driver for primary production directly and indirectly (Hamdan, 2021).

The nutrient concentrations of nitrite and nitrate) in the current study were 1.04-19.91 µg/L and 21.51-251.79 µg/L, respectively (Figures 6 and 7), and there was a

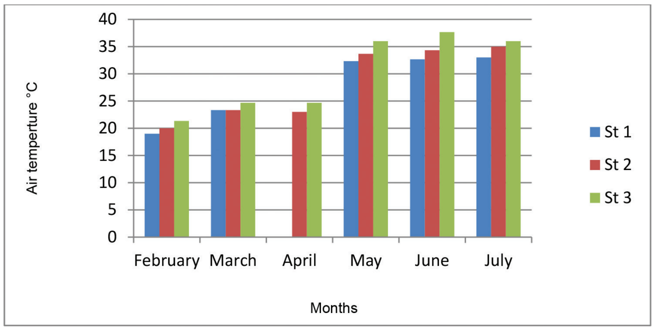

Figure 2: Monthly variations in air temperature °C mean value in sawa lake during the study periods.

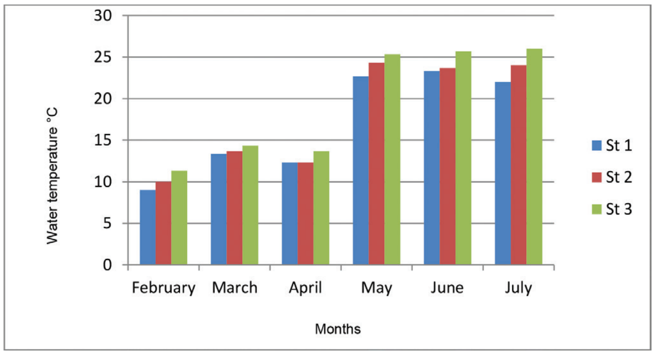

Figure 3: Monthly variations in water temperature mean value in Sawa lake during the study periods.

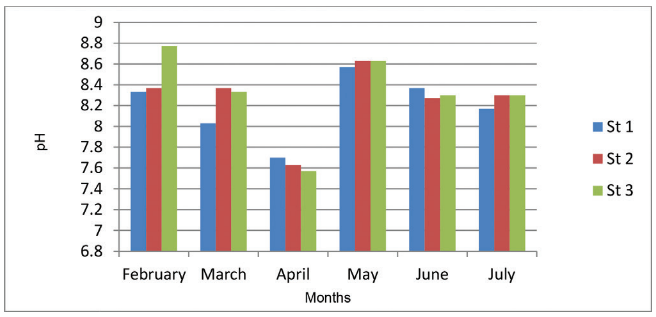

Figure 4: Monthly variations in pH mean value in Sawa lake during the study periods.

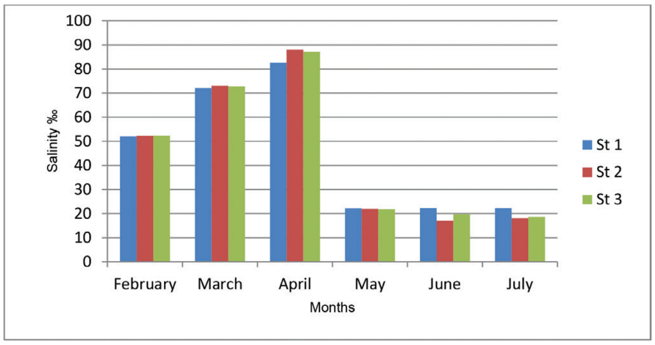

Figure 5: Monthly variations in salinity ‰ mean value in Sawa lake during the study periods.

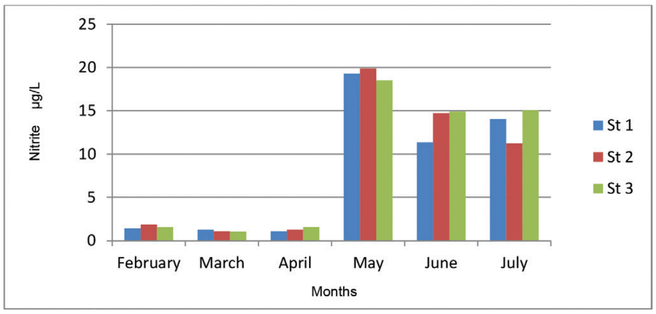

Figure 6: Monthly variations in NO_2^- µg/L mean value in Sawa lake during the study periods.

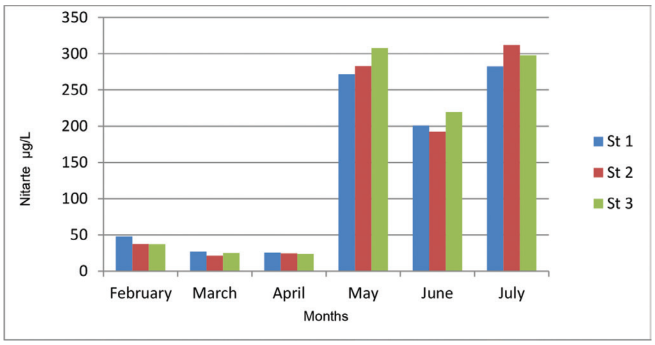

Figure 7: Monthly variations in NO_3^- µ g/L mean value in Sawa lake during the study periods.

reverse correlation with salinity. The increase in nitrate concentration in this current study is due to the increase in the reduction of nitrate to nitrite at high temperatures and is agreed with the results (Al-Taee, 2018; Mosley, 2015). Nutrient concentrations were generally lower, owing to decreased or absent input from watersheds. Increased nutrient concentrations once the water returns, on the other hand, have been associated with less dilution of groundwater drainage input, even if dissolved nutrients can persist at low concentrations owing to algal absorption. Dissolved nutrient ratios have been seen to vary, which might impact primary output due to nutrient constraints. Concerning nutrient enrichment status, Sawa Lake can be an oligotrophic lake. Primary productivity generally increases in conditions where the high nutrient concentrations are optimum.

Phosphate is one of the primary and essential nutrients limiting phytoplankton growth because it is few in water. The lowest value was 0.26 µg/L in May at site 3 and the highest value was recorded at 2.37 µg/L in March at site 3 (Figure 8) did not record a moral difference between sites during the statistical analysis while there was a moral difference between months at the probability level ($p > 0.05$). This result is due to the lack of human activities, bird faeces, low water levels and abundance of phytoplankton, and this study agrees with the study of Gwiazda et al. (2014) and Jeppesen et al. (2005).

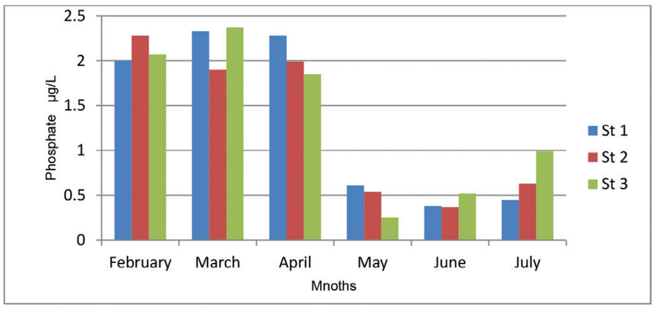

Figure 8: Monthly variation in phosphate Po_4^{-3} µg/L mean value in Sawa lake during the study periods.

Primary Productivity

The productivity measured by the light and dark bottles method recorded the lowest level (0.25 mg/m^3/h) in February, and the highest level (3.25 mg/m^3/h) was observed in July (Figure 9). The greatest values were found during the summer months when clarity and water temperature peaked and were strongly linked to salinity (r =-0.63). The statistical analysis did show significant differences within the sites at the probability level ($p > 0.05$). In contrast, the decrease in these values may be due to the decrease in water temperature and lake drought, which led to a decrease in aquatic organisms' biological activities, including phytoplankton. This result was similar to previous studies (Borrego-Marín et al., 2016; Lewandowsky et al., 2012; Vander Molen and Perissinotto, 2011).

Chlorophyll-a is one of the parameters that significantly determines the primary productivity in the water. The results of primary productivity measurements based on the value of chlorophyll-a concentration the lowest value of concentration was (0.11 mg/L) in April at site 1 and the highest chlorophyll-a concentration (3.17 mg/L) in July at site 3 (Figure 10). Chlorophyll is a pigment found in algae, and when the lake is dry, algae growth decreases, and therefore chlorophyll concentration has decreased. The increase in the concentration of chlorophyll after the drought period and the return of the water level due to phytoplankton blooms as a result of the temperatures moderation and the nutrients abundance. This study is similar to Ayeni et al. (2018) and Hassan et al. (2010. According to Ndungu et al. (2013), there is an inverse link

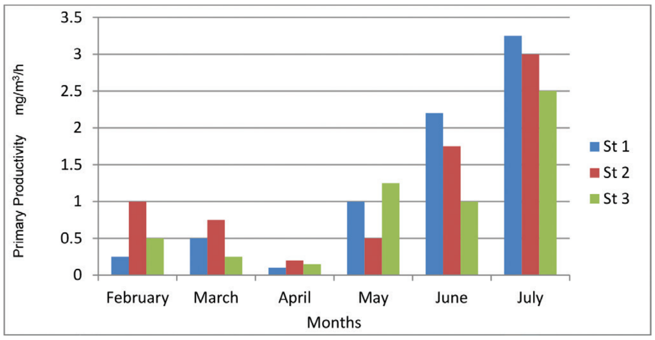

Figure 9: Monthly variation in primary productivity mg/m^3/h mean value in Sawa lake during the study periods.

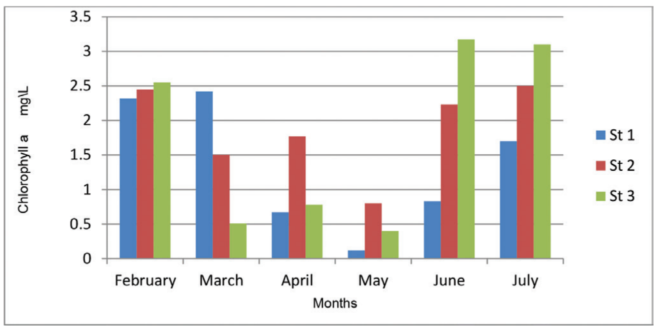

Figure 10: Monthly variation in chlorophyll-a mg/L mean value in Sawa lake during the study periods.

between chlorophyll-a and water level, the availability of nutrients in the absence of zooplankton predation leads to massive phytoplankton production. Hence, increase in chlorophyll-a. The content of chlorophyll-a in phytoplankton is a good indicator of the productivity of water, which indicates that good water quality helps the phytoplankton to thrive. In conclusion, the drought for the lake occurred as a result of a series of reasons that were strongly influenced by human activities. Traditionally, groundwater is used for agricultural purposes in this region. Thus, the rate of groundwater flows into the lake decreases, which negatively affects the physical and chemical parameters and thus affects the productivity of the lake.

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