

ASSESSMENT OF PHYSICO-CHEMICAL CONDITIONS AND PLANKTON DIVERSITY OF AGULU LAKE IN ANAMBRA STATE.

Amakiri M., Anyanwu J.C., Njoku P. C., and Loe N.

**Department: Environmental Management, Federal University of Technology, Owerri,
Imo State, Nigeria**

ABSTRACT

Rivers and lakes are constantly polluted in recent years through runoff and human activities. This have resulted in the deterioration of the water quality of these water bodies, and in some cases have resulted in the phenomenon of eutrophication which have serious impact on the plankton composition and physico-chemical properties of the water bodies. Eutrophication of water bodies are greatly accelerated by the activities of man. This degradation of water quality has had tremendous adverse effects on the aquatic ecosystem as well as on man. Agulu Lake are daily enriched with nutrients responsible for eutrophication (nitrates and phosphates). These nutrients find their way into the lake through the numerous anthropogenic activities taking place in and around the areas. The degradation of the water bodies is as a result of dumping of wastes, agricultural activities, sewage disposal, discharge of effluents, use of detergents and defecation. The attendant adverse effect of the degradation of the water bodies include variation in the physico-chemical properties and plankton composition in relation to season. Also, the water quality which serve as sources of drinking water and other domestic activities for the inhabitants of the areas is affected. ; plankton composition can serve as indicator of pollution of the lake. There is need to identify the plankton communities of this lake so as to detect changes in the community structure. The focus of the study is to evaluate the physico-chemical conditions of Agulu Lake in Anambra State, and to assess the composition and abundance of plankton assemblage of the lake. The results showed that the variations in physicochemical parameters and plankton diversity which is in abundance in Agulu lake is a reflection of the anthropogenic activities around the drainage basins of the rivers which impact significantly on the water quality. The study also revealed that the lake sustains dense populations of phytoplankton and zooplankton species and the reduction of both phytoplankton and zooplankton diversities was as a result of human activities.

Keywords: Physico-Chemical, Parameters, Phytoplankton, Zooplankton and Diversities

INTRODUCTION

A lake is a naturally occurring, relatively large body of water localized in a basin or interconnected basins surrounded by dry land. Lakes lie completely on land and are separate from the ocean, although, like the much larger oceans, they form part of the Earth's water cycle by serving as large standing pools of storage water. Most lakes are freshwater and account for almost all the world's surface freshwater, but some are salt lakes with salinities even higher than that of seawater (Seekell, Cael, Lindmark and Byström, 2021). Lakes are typically much larger and deeper than ponds, which are also water-filled basins on land, although there are no official definitions or scientific criteria distinguishing the two. Most lakes are fed by springs, and both fed and drained by creeks and rivers, but some lakes are endorheic without any outflow, while volcanic lakes are filled directly by precipitation runoffs and do not have any inflow streams. Lakes are also distinct from lagoons, which are shallow tidal pools dammed by sandbars at coastal regions. Natural lakes are generally found in mountainous areas (i.e. alpine lakes), dormant volcanic craters, rift zones and areas with ongoing glaciation. Other lakes are found in depressed landforms or along the courses of mature rivers, where a river channel has widened over a basin formed by eroded floodplains and wetlands. Some parts of the world have many

lakes formed by the chaotic drainage patterns left over from the last ice age. All lakes are temporary over long periods of time, as they will slowly fill in with sediments or spill out of the basin containing them (Williams, Whitfield, Biggs, Jeremy; Simon; Gill & Pascale, 2004). Artificially controlled lakes are known as reservoirs, and are usually constructed for industrial or agricultural use, for hydroelectric power generation, for supplying domestic drinking water, for ecological or recreational purposes, or for other human activities (Kuusisto & Hyvärinen, (2000).

Lakes are important systems of biodiversity and are among the most productive ecosystems on the earth because of the favorable conditions that supports number of flora and fauna. They play a vital role in productivity as they are beset with varieties of flora and fauna including planktons. Urbanization, expansion of irrigation and increasing trend of industrialization has contributed towards the demand for water. Most of the fresh water bodies all over the world are getting polluted water, thus decreasing the portability of the water (Dumont and Negrea (2002). The concept of sustainable utilization by maintaining the natural properties of the wetland ecosystem becomes a practical reality only by a proper assessment of the relation between the parameters of water with the plankton, understanding its delicate functioning and by creating an increasing awareness about its ecological value. Several interdependent and influencing abiotic factors along with high primary productivity have made it a suitable niche for many aquatic forms. (Huisman et al 2011) reported that plankton community is a dynamic system that would quickly respond to changes in the physical and chemical properties of the water environment because they represent the base-line of the food chain in the aquatic ecosystem. Their positioning in the food chain, with a high degree of connection with the primary producer, makes them extremely susceptible to structural and environmental changes occurring at this trophic level, thus they act as indicators of water quality (Jung, Lajoie and Marcarelli 2017). It has been reported that the standing crop and species composition of phytoplankton indicate the quality of water because of their short life cycles and ability to respond to environmental changes (*Downing et al 2026*). Plankton consists of phytoplankton and zooplankton. Phytoplanktons are the autotrophic components of the plankton community while zooplanktons are microscopic animals. They are found in oceans, seas, river, lakes, and ponds. According to (Saifullah *et al.*, 2014), Phytoplanktons are the initial biological components from which the energy is transferred to higher organisms through food chain. They are important in the production of basic food in the ecosystem, hence they are producers in the aquatic ecosystem. They occur as unicellular, colonial or filamentous forms, without any resistance to currents and are minute, free-floating or suspended in the open waters (Hasssan and Al Saadi, 1995). When in abundance, they give greenish colour to the water. They are mainly the cladophora, spirogyra, zygnum, oedogonium, ulothrix, and several others. There are also a number of diatoms, e.g Anabaena and flagellates such as spriulina, chlamydomonas, microcystis, and many others. The zooplanktons include protozoans like Euglena, Coleps, Dileptus and others; rotifers like Asplanchna, Brachionus and Leeane. They also include crustaceans like Cyclops, Stenocypris, etc. Zooplankton feed mainly on phytoplankton. Changes in the phytoplankton community are rapidly affected by the zooplankton because of their short life cycles; this makes the zooplankton community a key element for the understanding of the changes occurring in aquatic ecosystems. Pollutants from domestic and industrial wastes, heavy metals, organic wastes among many others into the aquatic ecosystem constitute public hazards (Anyanwu, et al., 2020; Arimoro and Osakwe, 2006). WHO (2003) however, noted the need to protect the water bodies from deterioration, chronic or intermittent health hazards and loss of aesthetics and recreational values.

Zooplankton are the animal component of the planktonic community. Plankton are aquatic organisms that are unable to swim effectively against currents. Consequently, they drift or are carried along by currents in the ocean, or by currents in seas, lakes or rivers (Arunava and Chakraborty 2018). Zooplankton can be contrasted with phytoplankton, which are the plant component of the plankton

community. Zooplankton are heterotrophic (other-feeding), whereas phytoplankton are autotrophic (self-feeding). In other words, zooplankton cannot manufacture their own food. Rather, they must eat other plants or animals instead. In particular, they eat phytoplankton, which are generally smaller than zooplankton. Most zooplankton are microscopic but some (such as jellyfish) are macroscopic, meaning they can be seen with the naked eye, Arunava and Chakraborty 2018). Many protozoans (single-celled protists that prey on other microscopic life) are zooplankton, including zooflagellates, foraminiferans, radiolarians, some dinoflagellates and marine microanimals. Macroscopic zooplankton include pelagic cnidarians, ctenophores, molluscs, arthropods and tunicates, as well as planktonic arrow worms and bristle worms. The distinction between plants and animals often breaks down in very small organisms. Recent studies of marine microplankton have indicated over half of microscopic plankton are mixotrophs. A mixotroph is an organism that can behave sometimes as though it were a plant and sometimes as though it were an animal, using a mix of autotrophy and heterotrophy. Many marine microzooplankton are mixotrophic, which means they could also be classified as phytoplankton, (Arunava and Chakraborty 2018). Zooplankton, the diverse group of small aquatic animals that drift in water bodies, play a vital role in marine and freshwater ecosystems. As primary consumers of phytoplankton and secondary prey for larger predators, they are an essential component of food webs in aquatic environments. Due to their ecological importance, understanding zooplankton ecology is crucial for the assessment and management of aquatic resources. One of the critical functions of zooplankton in aquatic ecosystems is their role as grazers on phytoplankton. They consume large quantities of phytoplankton, thereby limiting their abundance and preventing excessive algal blooms (Jiang *et al.*, 2019). Zooplankton grazing also helps regulate the nutrient cycle as they excrete nutrients that are important for the growth of phytoplankton.

In addition to their role as grazers, zooplankton also act as prey for a wide range of organisms, including fish, birds, and larger invertebrates. By providing a food source for higher trophic levels, zooplankton support the entire food web of aquatic ecosystems (Michaelidis *et al.*, 2020).

Zooplankton ecology is also impacted by environmental changes, such as climate change and nutrient pollution. There is growing evidence that climate change is affecting zooplankton community structure, with some species being more vulnerable to warming than others (Kettunen *et al.*, 2005). Furthermore, excessive nutrient inputs from human activities can alter the composition and abundance of zooplankton communities, which can in turn affect the entire food web (Maugars *et al.*, 2019). The distribution of zooplankton in water bodies is influenced by physical and chemical parameters, such as temperature, salinity, pH, light, turbulence, and nutrient availability. Similarly, the behavior of zooplankton, such as vertical migration, diel feeding, and predator avoidance, is crucial for their survival and reproduction (Hays *et al.*, 2018).

Interactions with other organisms in the aquatic ecosystem, including predators, competitors, parasites, and symbionts, play a vital role in structuring zooplankton communities. Predation is a significant cause of mortality for zooplankton, and they have evolved various adaptations, such as transparency, spines, and rapid swimming, to avoid or deter predators (Weber *et al.*, 2013).

Parasites and symbionts also affect the physiology, behavior, and population dynamics of zooplankton, and their interactions may have significant implications for the functioning of aquatic ecosystems (McLaughlin and Marcogliese, 2019). Finally, anthropogenic activities, such as eutrophication, pollution, and climate change, have severe impacts on zooplankton ecology. Eutrophication, caused by excessive nutrient loading, can lead to the proliferation of harmful algal blooms, which can be toxic to zooplankton. Pollution from industrial and agricultural activities can also expose zooplankton to toxic substances, reducing their survival and reproductive success. Climate change, particularly warming and acidification of water bodies, can also affect zooplankton physiology, behavior, and distribution, with potentially major consequences for the entire aquatic ecosystem (Gamble *et al.*, 2020). The zooplankton

community is a strategic compartment in the energy flow in aquatic ecosystems and in the maintenance and orientation of the aquatic trophic webs. The study of zooplankton ecology provides critical insights into the functioning of aquatic ecosystems, their responses to environmental changes, and their management and conservation. This study evaluated the physico-chemical conditions of Agulu Lake in Anambra State, and the composition and abundance of plankton assemblage of the lake is assessed.

MATERIALS AND METHOD

Collections of phytoplankton were made using a conical net of bolting nylon of 0.069mm mesh width and mouth ring diameter of 35 cm with the help of an outrigger canoe. The net was towed for ten minutes for surface hauls and the volume of water filtered through it was determined by flow meter attached to it and the net was backwashed between the stations to avoid clogging of meshes. The filtered samples were fixed and preserved in 4% formalin with a few drops of Lugol's iodine solution. For the quantitative analysis of phytoplankton, the settlement method described by Mille-Lindblom and Jeppesen (2021) was adopted. Numerical plankton analysis was carried out using an inverted microscope. Planktons were identified and enumerated by using the methods described by Jackson, Williams and Joint (1987)

The zooplanktons were collected with the use of plankton nets of size 50 μm which was used to drag through horizontally and vertically on the lake. The sampling was done in the morning before 8:00 am between the months of April to September, 2021. Pour-through method was used to collect the samples. A 10-liter graduated bucked was used to collect water at a depth of about 30cm below the water surface and then poured into a plankton net of mesh size 50 μm , this was done 10 times to make a total of 100 litres of filtered water. The collected zooplankton were then carefully transferred into properly labeled storage containers, 4% of formalin was then added to serve as a preservative for the zooplankton. The samples were taken to the laboratory for further analysis. The water samples were collected with sterile containers, properly labeled, stored in a refrigerator and taken to the laboratory within 72 hours of collection for analysis of physicochemical parameters of the lake.

The averages and the relationship of the collected data will be assessed using descriptive statistics and correlation.

The average of each Physio-Chemical Parameter (X_i) in location (S_j) is determined by

$$\bar{X}_i = \frac{\sum_{j=1}^m X_j}{m} \quad (1)$$

where, i is the Physio-Chemical Parameter, j is the location. i ranges from 1 to n while j ranges from 1 to m . That is $i = 1, 2, \dots, 18$ and $j = 1, 2, \dots, 6$

The relationship between the Physio-Chemical Parameter across the location is assessed using Pearson product moment correlation coefficient (r).

The correlation coefficient is a measure of the strength and the direction of a linear relationship between two variables, say, X and Y. It is given by r

where,

$$r = \frac{n \sum xy - (\sum x)(\sum y)}{\sqrt{n \sum x^2 - (\sum x)^2} \sqrt{n \sum y^2 - (\sum y)^2}} \quad (2)$$

n is the number of data pairs and the value of the correlation lies between $-1 \leq r \leq 1$.

In this work, the following decision rules applies to the result of the correlation analysis.

1. A correlation coefficient of $r = +1$ indicates a perfect positive correlation. This implies that as variable X increases, variable Y increases or as variable X decreases, variable Y decreases.
2. A correlation coefficient of $r = -1$ indicates a perfect negative correlation. That is, as variable X increases, variable Y decreases. As variable X decreases, variable Y increases.
3. A correlation coefficient near 0 indicates no correlation.

RESULT AND DISCUSSION

The data for this study is presented in Appendix.1 through Appendix 3. Figure 1 show the Physico-Chemical parameters of Agulu Lake for the six sampling points for the data in Appendix 1. The sample mean of the sample points was compared for difference. The study utilized Analysis of Variance (ANOVA) test to determine if there is a statistical difference in sample mean among the parameters. The result of the ANOVA test is shown in Table 1, while the correlation is shown in Table **Test of hypothesis**

Ho: there is no statistical difference in sample mean among the parameters

H1: there is statistical difference in sample mean among the parameters

Decision Rule

1. Accept H_0 and reject H_1 , if P – value is greater than 0.05(level of Significance)
2. Otherwise, Reject H_0 and accept H_1 .

Table 1: ANOVA test for difference in mean

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Sampling_Points	5	296.8	59.37	0.41	0.839
Error	102	14667.9	143.80		
Total	107	14964.8			

Interpretation: Since the P – value in Table 1 (0839) is greater than 0.05, the study concludes that there is no statistical difference in sample mean among the parameters.

Correlation Analysis of Physicochemical parameters of Agulu Lake

The result of the correlation of the data in Appendix 1 (Mean values of the Physico-Chemical characteristics of Agulu lake) is given in the correlation Matrix in Table 2.

Table 2: Correlation Analysis of Physicochemical parameters of Agulu Lake

	Temp	pH	Turb	EC	TDS	TSS	TS	DO	BOD	COD	CI	Ca	T_ALK	THD	PO4	K	NO2	Na
Temp	1	.352	-.050	-.143	.279	.025	.247	.134	.059	.005	.287	-.395	.729	-.047	-.290	.164	.218	.247
pH	.352	1	.845	.863	.528	.749	.569	.451	.638	.672	.276	.514	-.207	.800	.565	.698	.414	.629
Turb	-.050	.845	1	.965	.893	.926	.912	.822	.927	.922	.641	.858	.535	.981	.769	.572	.834	.856
EC	-.143	.863	.965	1	.817	.968	.852	.783	.934	.916	.577	.799	.506	.956	.808	.638	.772	.901
TDS	.279	.528	.893	.817	1	.873	.998	.953	.936	.865	.857	.980	.761	.916	.661	.345	.962	.862
TSS	.025	.749	.926	.968	.873	1	.905	.864	.962	.880	.717	.886	.677	.954	.728	.585	.813	.963
TS	.247	.569	.912	.852	.998	.905	1	.95	.955	.881	.851	.982	.761	.936	.682	.385	.956	.890
DO	.134	.451	.822	.783	.953	.864	.955	1	.924	.790	.931	.923	.692	.895	.652	.151	.932	.811
BOD	.059	.638	.927	.934	.936	.962	.955	.924	1	.949	.744	.911	.653	.944	.832	.461	.935	.935
COD	.005	.672	.922	.916	.865	.880	.881	.790	.949	1	.530	.812	.505	.879	.920	.560	.903	.869
CI	.287	.276	.641	.577	.857	.717	.851	.931	.744	.530	1	.867	.757	.758	.331	.020	.778	.670
Ca	-.395	.514	.858	.799	.980	.886	.982	.923	.911	.812	.867	1	-.867	.891	.559	.425	.908	.904
T_ALK	.729	.207	.535	.506	.761	.677	.761	.692	.653	.505	.757	.867	1	.589	.185	.422	.654	.796

THD	-.047	-.800	.981	.956	.916	.954	.936	.895	.944	.879	.758	-.891	.589	1	.722	.474	.845	.869
PO4	-.290	.565	.769	.808	.661	.728	.682	.652	.832	.920	.331	.559	.185	.722	1	.377	.782	.678
K	.164	.698	.572	.638	.345	.585	.385	.151	.461	.560	.020	.425	.422	.474	.377	1	.254	.667
NO2	.218	.414	.834	.772	.962	.813	.956	.932	.935	.903	.778	.908	.654	.845	.782	.254	1	.813
Na	.247	.629	.856	.901	.862	.963	.890	.811	.935	.869	.670	.904	.796	.869	.678	.667	.813	1

Temp = Temperature, Turb = Turbidity, EC = Electrical Conductivity, TDS = Total Dissolved Solids, TSS = Total Suspended Solids, TS = Total Solids, DO = Dissolved Oxygen, BOD = Biological Oxygen Demand, COD = Chemical Oxygen Demand, Cl⁻ = Chloride, Ca = Calcium, T Alk = Total Alkalinity, T HD = Total Hardness, PO₄ = Phosphate, K = Potassium, NO₂ = Nitrate, Na = Sodium

Interpretation:

It can be seen that for almost all combination of the Physicochemical parameters compared in Table 2, there is a strong positive correlation. Hence, it can be generalized that there is a significant relationship between any two pair of Physicochemical parameters indicating that the Physicochemical parameters tend to increase together.

Correlation Analysis between Phytoplankton and Zooplankton Diversity and Physicochemical characteristics

The joint correlation Analysis for the data in Apendix 2 and Appendix 3; between Phytoplankton and Zooplankton Diversity and Physicochemical characteristics of Agulu Lake are shown in Table 3.

Table 3: Correlation Analysis between Phytoplankton and Zooplankton Diversity and Physicochemical characteristics of Agulu Lake

		Phytoplankton			Zooplankton			
		Bacillariophyceae	Chlorophyceae	Cyanophyceae	Protozoans	Crustaceaa	Rotifera	Insecta
Phytoplankton	Bacillariophyceae	1	.687	.825	.389	.483	.789	.585
	Chlorophyceae	.687	1	.965	.410	.703	.502	.940
	Cyanophyceae	.825	.965	1	.414	.731	.695	.884
	Protozoans	.389	.410	.414	1	-.263	-.017	.607
Zooplankton	Crustaceaa	.483	.703	.731	-.263	1	.728	.536
	Rotifera	.789	.502	.695	-.017	.728	1	.331
	Insecta	.585	.940	.884	.607	.536	.331	1

Interpretation:

The results of correlation analysis between Phytoplankton and Zooplankton Diversity and Physicochemical characteristics of Agulu Lake in Table 3 revealed that, Phytoplankton diversity; Bacillariophyceae, Chlorophyceae and Cyanophyceae correlated highly positive with the Zooplankton diversity; Protozoans, Crustaceaa, Rotifera and Insecta ($r = 0.825, 0.789, 0.965, 0.703, 0.940, 0.731, 0.884$ and 0.728) and negatively correlated with ($r = -0.263$ and -0.017).

CONCLUSION

The present study provides important information on plankton distribution and abundance of the Agulu lake which may provide insight on the energy turnover of the lake. The dominant phytoplankton assemblage of the lake reflects its trophic levels. The study revealed that the abundance and diversity of plankton species differ based on the locations which could be attributed to varying human activities in the lake. Even though the lake differ in age, chemistry and type of inflows, it maintained phytoplankton overwhelmingly dominated by Chlorophyceae members, specifically *Chlorella*, *Cladophora* and *Spirogyra*. The planktonic community exhibited changes in response to changes in physicochemical characteristics of the rivers. The variations in physicochemical parameters and plankton diversity and abundance of the lake is a reflection of the anthropogenic activities around the drainage basins of the lake which impact significantly on the water quality. The study revealed that the lake sustain dense populations of phytoplankton and zooplankton species. The high mean values of temperature recorded in lake could have contributed to the dominance of algae species (Chlorophyceae) in the lake. Similarly, most sample points with high pH values recorded great diversity of plankton species. The sampling station 1 recorded higher density of phytoplankton compared to other sampling stations. This could be due to anthropogenic activities, such as agricultural activities, waste disposal, laundry, bathing, commercial activities and cottage industries, in those stations. The physicochemical parameters of the lake have been significantly impacted by human activities thus resulting in reduction of both phytoplankton and zooplankton diversities.

RECOMMENDATIONS

To reduce further degradation of the water quality and planktonic diversity of the rivers, the following recommendations are made:

- i. Activities around the catchment of the rivers should be monitored since they have significant effect on the water quality as revealed by the variations in physicochemical characteristics and phytoplankton diversity.
- ii. Measures should be taken by the relevant authorities to abate further deterioration of the lake.
- iii. There is need for urgent management and conservation strategies to protect and restore the water quality of the lake.
- iv. Remarkably little attention is given to the alarming loss of wetlands in the study area. Hence, there is a need to create awareness in public about the loss and to conserve and restore these natural resources.

Disclaimer (Artificial Intelligence)

Author(s) hereby declares that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

Competing interests

Authors have declared that no competing interests exist.

REFERENCE

Anyanwu, J.C, Rufus, U.N, Duluora, D.O, Egbuawa, O.I., Nwogbu E.O., Onwuagba C.J (2020)
Comparative analysis of heavy metals in carica papaya (pawpaw) fruit and soils in selected

urban, rural and forested land in Owerri Imo State. International Journal of Advanced Research 8:3 (10-20).

- Arunava, P. & Chakraborty, M. (2018). Zooplankton biodiversity and composition in a reservoir of West Bengal. Journal of Entomology and Zoology Studies, 6(2), 1128-1135.
- Downing, J.A.; Prairie, Y. T.; Cole, J.J.; Duarte, C.M.; Tranvik, L.J.; Striegl, R.G.; McDowell, W.H.; Kortelainen, P.; Caraco, N.F.; Melack, J.M. (2006). "The global abundance and size distribution of lakes, ponds, and impoundments". *Limnology and Oceanography*. **51** (5): 2388–2397.
- Dumont, H.J., Negrea, S.V. (2002) Introduction to the class Crustacea. In: Dumont, H.J. (ed.) Guides to the Identification of the Microinvertebrates of the Continental Waters of the World. BackhuysPublishers, Leiden, pp. 47-123.
- Gamble, A., Brierley, A.S., Robison, B.H. (2020) Climate-induced changes in the Arctic pelagic ecosystem: a review of the recent progress in observations and modeling. Progress in Oceanography, 181, 102254-102266.
- Hays, G.C., Christensen, A., Fuentes, M.M.P.B., Letessier, T., Lyon, J., Meeuwig, J.J., Mortimer, J.A., Richardson, A.J., Smithers, S.G. (2018) Key questions in marine megafauna movement ecology. Trends in Ecology and Evolution, 33, 463-475.
- Huisman, S.M., Mittelbach, G.G., Litchman, E. and Klausmeier, C.A. (2011), Large-scale biodiversity patterns in freshwater phytoplankton. Ecology, 92: 2096-2107
- Jackson, R.H Williams, P.B., Joint, I.R (1987) Freshwater phytoplankton in the low salinity region of the River Tamar estuary, Estuarine, Coastal and Shelf Science, Volume 25, Issue 3, 1987, Pages 299-311,
- Jiang, Z., Li, B., & Zhao, Y. (2019). Zooplankton grazing and nutrient limitation in a eutrophic lake: Implications for trophic state assessments. Journal of Environmental Sciences, 83, 118-126.
- Jung, J., Lajoie, K.R., Marcarelli, A.M. (2017) High-throughput amplicon sequencing of rRNA genes and quantitative PCR assays for detection of eutrophication-associated microbiota and organisms in freshwater lakes. Inland Waters, 7, 3-13.
- Kettunen, M., Hynynen, J., Hermansson, M., Högmander, H., Isokangas, E., Kärkkäinen, S., Koskiahio, J., Mikkola, H., Muotka, T., Stén, A., Virtanen, R. (2005). A zooplankton-based tool for assessing the ecological status of lakes in Finland. Hydrobiologia 547, 109-121.
- Kuusisto, E; Hyvärinen, V (2000). "Hydrology of Lakes". In Pertti Heinonen (ed.). Hydrological and Limnological Aspects of Lake Monitoring. John Wiley & Sons. pp. 4–5. ISBN 978-0-470-51113-8.
- Luo, S., Mille-Lindblom, C., Jeppesen, E. (2021) Salinity as a driver of zooplankton communities in freshwater and brackish lakes and impoundments. Hydrobiologia, 847, 109-125.

- Maugars, G., Lefèvre, D., & Kim, S. Y. (2019). Phytoplankton and zooplankton responses to nutrient enrichment in shallow coastal waters: A mesocosm study. *Marine Environmental Research*, 144, 163-174.
- McLaughlin, J.D., Marcogliese, D.J. (2019) Parasitology as an integrative scientific discipline. *Trends in Parasitology*, 35, 801-815.
- Michaelidis, B., Galgani, F., & Papatheodorou, G. (2020). Zooplankton diversity and dynamics in the northeastern Mediterranean Sea: The influence of environmental conditions and hydrodynamic processes. *Journal of Marine Systems*, 211, 103317.
- Seekell, D.; Cael, B.; Lindmark, E.; Byström, P. (2021). "The Fractal Scaling Relationship for River Inlets to Lakes". *Geophysical Research Letters*. **48** (9)
- Weber, A.A.-T., Haas-Assenbaum, A., Eckerlebe, S., Kruse, P.D., Sommer, U. (2013) Inducible defenses in Planktonic Copepods: a review. *Journal of Plankton Research*, 35, 1275-1287.
- Williams, P; Whitfield, M; Biggs, Jeremy; B, Simon; F, Gill; N, Pascale; S, (2004). "Comparative biodiversity of rivers, streams, ditches and ponds in an agricultural landscape in Southern England" (PDF). *Biological Conservation*. 115 (2): 329–341. doi:10.1016/S0006-3207(03)00153-8. Archived from the original (PDF) on 12 September 2011. Retrieved 16 June 2009.

Appendix 1

Mean values of the Physico-Chemical characteristics of Agulu lake

Parameters	Sampling Points (Locations)					
	S1	S2	S3	S4	S5	S6
Temperature °C	27	27.6	27.2	27.6	27.1	27.0
pH	7.02	7.30	7.46	7.64	7.22	7.60
Turbidity (FTU)	4.21	3.80	3.52	3.01	3.26	2.81
Conductivity μohmCm^{-1}	30.6	24.5	22.9	20.8	22.0	18.4
TDS mg/l	19.24	18.02	16.41	10.22	6.07	2.62
TSS mg/l	6.20	4.61	4.44	4.16	3.87	2.71
TS mg/l	25.44	22.63	20.85	14.38	9.94	5.33
Total Alkalinity mg/l	18.6	16.0	18.2	14.5	12.1	10.8
Total Hardness mg/l	56.2	48.9	48.0	44.6	40.5	38.7
Calcium mg/l	9.60	7.33	5.18	4.06	2.92	3.48
Chloride mg/l	4.64	4.23	5.55	4.14	3.26	2.09
DO mg/l	6.0	6.5	8.4	10.6	14.2	18.6
COD mg/l	6.4	6.8	6.2	6.9	5.6	4.5
BOD mg/l	22.04	18.70	18.64	15.02	16.11	12.65
Phosphate mg/l	0.02	0.01	0.008	0.004	0.001	0.008
Potassium mg/l	2.83	2.62	1.06	2.08	2.34	1.51
Nitrate mg/l	2.8	2.6	2.5	2.0	1.4	1.6
Sodium mg/l	2.70	2.30	2.02	2.20	1.86	1.52

Appendix 2

Distribution of phytoplankton (Unit/l) in Agulu Lake during the study period

	Sampling Points						
Phytoplankton							
Bacillariophyceae	S1	S2	S3	S4	S5	S6	Total
<i>Achnanthes devei</i>	20	18	9	8	5	3	63
<i>A. bisoletiana</i>	10	10	7	4	8	6	25
<i>Cyclotella</i>	17	10	3	6	4	2	42
<i>Fragillaria pinnata</i>	10	8	4	2	10	4	38
<i>Diatoms</i>	30	22	18	10	10	8	98
<i>Nitzschia spp.</i>	0	2	0	1	2	5	10
<i>Navicula spp.</i>	16	10	14	8	6	4	58
Total	103	80	55	39	45	32	334
Chlorophyceae							
<i>Chlorella</i>	10	8	13	10	6	8	55
<i>Cladophora</i>	15	4	3	9	8	10	49
<i>Oedogonium</i>	6	4	0	8	3	3	24
<i>Closterium spp.</i>	10	5	3	3	2	6	29
<i>Spirogyra</i>	15	10	7	10	10	8	50
<i>Ulothrix</i>	10	6	4	8	10	5	43
<i>Microspora</i>	7	5	8	3	0	3	26
<i>Zygnema</i>	2	1	4	4	8	2	21
<i>Tetraspora</i>	10	5	3	2	4	0	24
<i>Volvox</i>	7	5	4	10	2	3	31
Total	92	53	49	67	53	48	352
Cyanophyceae							
<i>Anabena spp.</i>	10	6	3	8	3	5	35
<i>Oscillatoria spp.</i>	8	4	5	3	1	0	21
<i>Nostoc spp.</i>	2	0	3	5	1	2	13
<i>Spirulina</i>	5	2	0	2	1	5	15
<i>Nodularia</i>	12	4	6	8	10	4	44
<i>Rivularia spp.</i>	7	8	4	0	2	2	23
Total	44	24	21	26	18	18	151

Appendix 3

Distribution of Zooplankton (Unit/l) in Agulu Lake during the study period

ZOOPLANKTON	Sampling Points						
	S1	S2	S3	S4	S5	S6	Total
Protozoans							
<i>Paramaecium caudatum</i>	12	7	5	5	10	11	50
<i>Amoeba species</i>	10	5	3	4	6	4	32
<i>Sphaerophysa species</i>	2	3	1	0	4	1	11
<i>Carchesium polypium</i>	4	2	2	1	0	3	12
<i>Paramaecium Aurelia</i>	10	7	8	5	8	9	47
<i>Arcella species</i>	0	1	1	3	2	6	13
Total	38	25	20	18	30	34	165
Crustaceaa							
<i>Mesocyclops species</i>	5	2	3	5	0	4	19
<i>Nuplius larvae</i>	6	4	3	6	4	3	26
<i>Zoea larvae</i>	2	3	1	1	0	2	9
<i>Macrocylops species</i>	10	8	11	7	4	5	45
<i>Daphnia species</i>	2	4	2	7	3	2	20
<i>Diaphanosoma species</i>	6	5	8	3	6	5	33
<i>Nauplius species</i>	0	3	3	8	10	5	29
<i>Cyclops species</i>	11	5	8	4	3	4	35
Total	42	34	39	41	30	30	196
Rotifera							
<i>Diurella species</i>	10	13	10	6	2	5	46
<i>Keratella quadrata</i>	4	3	1	1	4	0	13
<i>Microcodon species</i>	7	5	4	2	2	6	26
<i>Brachionus caudatus</i>	14	7	10	6	2	5	44
<i>Gastropus hyptopus</i>	1	0	1	3	1	0	6
<i>Epiphanes macrourus</i>	8	10	12	7	4	6	47
<i>Lacane species</i>	0	2	2	3	1	2	10
<i>Asplachna species</i>	6	4	4	5	2	3	24
Total	50	44	44	33	18	27	216
Insecta							
<i>Chaoborus species</i>	6	5	3	6	7	4	31
<i>Siphonurus species</i>	0	1	2	1	0	3	7
<i>Anopheles larvae</i>	35	10	18	15	20	14	108
<i>Chironomus larvae</i>	8	5	1	8	2	5	29
Total	49	21	24	30	29	26	175